Global Power Best Practice Series 6

Strategies for Decarbonizing the Electric Power Supply

RAP Energy solutions for a changing world

Synapse Energy Economics, Inc.

Strategies for Decarbonizing the Electric Power Supply

Authors
Lucy Johnston
Rachel Wilson

November 2012

The Global Power Best Practice Series was funded by the Climate Works Foundation (CWF) and The Regulatory Assistance Project (RAP). The information and material provided in this series is general in nature. RAP and CWF make no warranty or guarantee regarding the accuracy of any forecasts, estimates or analyses contained in the Global Power Best Practice Series reports. RAP and CWF are not responsible for any liability in association with this content.

About the Global Power Best Practice Series

Worldwide, the electricity sector is undergoing a fundamental transformation. Policymakers recognize that fossil fuels, the largest fuel source for the electricity sector, contribute to greenhouse gas emissions and other forms of man-made environmental contamination. Through technology gains, improved public policy, and market reforms, the electricity sector is becoming cleaner and more affordable. However, significant opportunities for improvement remain and the experiences in different regions of the world can form a knowledge base and provide guidance for others interested in driving this transformation.

This Global Power Best Practice Series is designed to provide power-sector regulators and policymakers with useful information and regulatory experiences about key topics, including effective rate design, innovative business models, financing mechanisms, and successful policy interventions. The Series focuses on four distinct nations/regions covering China, India, Europe, and the United States (U.S.). However, policymakers in other regions will find that the Series identifies best — or at least valued — practices and regulatory structures that can be adapted to a variety of situations and goals.

Contextual differences are essential to understanding and applying the lessons distilled in the Series. Therefore, readers are encouraged to use the two supplemental resources to familiarize themselves with the governance, market, and regulatory institutions in the four highlighted regions.

The Series includes the following topics:

1. New Natural Gas Resources and the Environmental Implications in the U.S., Europe, India, and China
2. Policies to Achieve Greater Energy Efficiency
3. Effective Policies to Promote Demand-Side Resources
4. Time-Varying and Dynamic Rate Design
5. Rate Design Using Traditional Meters
6. Strategies for Decarbonizing the Electric Power Supply
7. Innovative Power Sector Business Models to Promote Demand-Side Resources
8. Integrating Energy and Environmental Policy
9. Policies to Promote Renewable Energy
10. Strategies for Energy Efficiency Financing
11. Integrating Renewable Resources into Power Markets

Supplemental Resources:

12. Regional Power Sector Profiles in the U.S., Europe, India, and China
13. Seven Case Studies in Transmission: Planning, Pricing, and System Operation

In addition to best practices, many of the reports also contain an extensive reference list of resources or an annotated bibliography. Readers interested in deeper study or additional reference materials will find a rich body of resources in these sections of each paper. Authors also identify the boundaries of existing knowledge and frame key research questions to guide future research.

Please visit www.raponline.org to access all papers in the Series.

This Global Power Best Practice Series was funded by the ClimateWorks Foundation www.climateworks.org

Table of Contents

Foreword

Policy makers around the world, in both developed and developing economies, have to make decisions today about how to avoid greenhouse gas emissions and the calamitous effects of climate change. These decisions are not only about avoiding tons of greenhouse gases; they are about the need to avoid the cheapest tons first.

An 80 percent worldwide reduction in GHG emissions below 1990 levels is a daunting task that will require not only reductions in the electric sector, but also in the emissions associated with buildings and light transportation. While the electric sector currently represents slightly more than 40 percent of today's emissions, due to its suitability as a substitute for more polluting forms of energy currently being used in the housing and light transport sectors, electricity use will need to increase.

However, this increased demand will need to be met with clean, low- and no-carbon energy supplies. Experience shows that putting a price on carbon will effect some positive change but, if relied on exclusively, the carbon price needed to meet our goals will be so high that the policy will not be feasible. Fortunately, there are many other policy options which, when combined with carbon pricing approaches, can deliver effective and low-cost carbon savings.

Energy efficiency continues to be the most cost-effective decarbonization strategy, and is discussed in depth in several other papers in this series. Here, we highlight other decarbonization policies, including the use of a carbon price through taxes and cap-and-trade, carbon intensity measures, resource planning, portfolio and contract standards, and complementary environmental standards. Technology strategies are also discussed, including carbon capture and storage, and renewable resources. Policies to discourage the use of fossil fuel resources and encourage the use of low-carbon resources are also explored.

Drawing on experience across the globe, *Strategies for Decarbonizing Electric Power Supply* presents a broad range of policy choices, which can be tailored to the specific circumstances in which they are implemented. It highlights examples of best practices for technology research and development, and for policy initiatives to foster deployment of those technologies.

Finally, *Strategies for Decarbonizing Electric Power Supply* drives home several fundamental observations. For maximum effect, a successful worldwide decarbonization effort will depend on the degree to which strategies are coordinated. Also, successful strategies will be those that contribute to sustained financial support for this transition from the status quo to a less carbon intensive sector, including light transport and buildings. Experiences today in Europe, China, and the United States are demonstrating the benefits of combining a carbon price with policies that complement pricing and more directly promote greater efficiency and the use of cleaner resources.

David Farnsworth
Senior Associate
Regulatory Assistance Project

1. Executive Summary

The scientific consensus has been that greenhouse gas (GHG) emissions reductions on the order of 80 percent from 1990 levels are necessary to avoid dangerous temperature increases. Now, however, scientists are indicating that even more drastic emissions reductions may be necessary because of delays in getting on the 80-percent reductions trajectory. At the December 2011 climate talks in Durban, South Africa, delegates from 194 countries agreed to begin talks that will lead to emissions reduction commitments from major GHG emitters, including the United States, China, and India. This agreement, which includes major emitters from developed and developing nations, is an important step forward.

Achieving even the global emissions reduction goal of 80 percent below 1990 levels is an enormous challenge. The electric sector will play a major role in achieving emissions reduction goals due to the volume of its emissions and the ability to substitute electricity for more polluting forms of energy use. It is the sector emitting the most GHGs, responsible for 41 percent of world CO_2 emissions. The task of decarbonizing the electric sector is a daunting one; the electric sector is not only the largest source of global GHG emissions, but trends indicate that electricity consumption will grow, despite energy efficiency policies. Fortunately there is already good progress in development of strategies to decarbonize the electric sector. End-use energy efficiency is the most economical decarbonization mechanism and will be an essential component in the transition to a low carbon electric sector. The focus of this paper is on the other components, which have to do with electric power supply.[1]

Both technology strategies and policy strategies for their promotion will be important components of this effort. The most important conclusion is that coordination of strategies, both technological and policy oriented, is essential to an effective and economical decarbonization effort. Strategies discussed in this paper focus on increasing efficiency of fuel conversion (e.g., through technological innovation, technology assistance among countries, output-based emissions standards, use of a carbon price, and government mandate); altering the mix of fossil fuels (e.g., through performance standards, planning processes, plant retirement due to mandate or economics); avoiding uncontrolled GHG emissions (e.g., development of carbon capture and sequestration, or CCS, technologies, policies prohibiting uncontrolled emissions, and establishing performance standards and CCS requirements); and reducing dependence on fossil fuels (e.g., development of zero-carbon technologies, use of a carbon price combined with complementary policies, resource planning, performance standards, and others). Strategies are under development across the world, with exciting innovation underway in the European Union (EU), China, Australia, India, the United States, and other locations. Implementation experience in different countries and geographic areas demonstrates that many policies have wide applicability, and that specific variations can be pursued to suit a particular circumstance.

Another main conclusion is that it is essential to adopt policies that will contribute to sustained financial support for a transition from the status quo to a less carbon-intensive sector (that includes light transport and buildings). A coordinated package of complementary policies and technology strategies is the most effective and economical approach to decarbonizing the electric sector. Experience in the European Union and the United States demonstrates the benefits of combining a carbon price with complementary policies to encourage and foster clean energy technologies. Although the institutional inertia of existing regulatory environments presents a significant challenge, transition is underway, and affected parties in various jurisdictions are slowly moving the mountain to establish a path for the electric sector to contribute to achieving long-term emissions reduction goals.

1 Other papers in the Global Power Best Practice Series address a variety of topics, including energy efficiency. To see other papers in the series, please visit www.raponline.org.

2. Introduction and Background

Since the 1992 United Nations Framework Convention on Climate Change (UNFCCC), nations throughout the world have discussed how to "achieve stabilization of atmospheric concentrations of greenhouse gases at levels that would prevent dangerous anthropogenic (human-induced) interference with the climate system…."

Scientific consensus has been that greenhouse gas (GHG) emissions reductions on the order of 80 percent from 1990 levels are necessary to avoid dangerous temperature increases.[2] Scientists are now indicating, however, that even this may not be enough due to delays in getting on a trajectory that would achieve the 80-percent emissions reductions goals.

A. International Agreements and Differing Circumstances

The Kyoto Accord of 1997 was the first major international agreement that included binding commitments for individual nations.[3] The Kyoto Protocol set binding emissions reduction targets for 37 industrialized nations, as well as the European Community, to reduce GHG emissions from 1990 emissions levels. However, this sort of agreement to reduce emissions from a historic baseline was not suitable to countries such as China, India, and others whose economies are undergoing significant development. A goal of emissions reduction from a historic baseline could bind a developing nation to a cap that would keep it from achieving economic growth and improvement in quality of life for its citizens. More workable measures for economies under development stem from analysis of the country's energy intensity or carbon intensity. The 2009 Copenhagen Accord embodies this approach in agreeing that developing countries should take "nationally appropriate mitigation actions."[4,5] China currently looks at climate change as a per-capita carbon intensity challenge; India's sustainability targets, announced in early 2011, include energy intensity targets for several industrial sectors and a market-based trading system for fine particles (in which fine particles serve as a proxy for other pollutants).

The Copenhagen Accord states that "deep cuts in global emissions are required according to science, and as documented by the IPCC [Intergovernmental Panel on Climate Change] Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius."

In December 2011 at climate talks in Durban, South Africa, delegates from 194 countries agreed to begin negotiations that will lead to emissions reduction commitments from major GHG-emitting nations, including the United States, China, and India.[6] This agreement is an important step forward, because it includes both developed and developing nations.

B. Consequences of Inaction and Delay

Although achieving scientifically based emissions goals is an enormous challenge, it is becoming increasingly clear

2 Metz, Davidson, Bosch, Dave, Meyer (eds), 2007

3 United Nations Framework Convention on Climate Change, 2012

4 For quantified economy-wide emission reduction targets for 2020 for Annex I countries, see http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5264.php. For nationally appropriate mitigation actions of developing country Parties, see http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

5 The Pew Center on Global Climate Change converted the 2020 pledges of 11 major economies into four common metrics: percent change in GHG emissions from 1990; percent change from 2005; percent change from "business as usual"; and percent change in emissions intensity from 2005. Pew Center on Global Climate Change (2011). Common Metrics: Comparing Countries' Climate Pledges. Retrieved from http://www.pewclimate.org/docUploads/country-pledge-brief.pdf

6 Holly, 2011

that this challenge must be met expeditiously. We cannot collectively afford a lengthy transition, for several key reasons:

1) Delay results in carbon lock-in as new investments continue in long-lived carbon emitting infrastructure in the electric sector;
2) Delay exacerbates climate change impacts and increases the likelihood of exceeding the two degrees Celsius target; and
3) Delay results in higher costs for achieving the scientifically based reduction targets.

Resource costs and technological innovation are key aspects of the challenge. Projections of social, economic, and environmental costs of continued high emissions are escalating as scientific understanding of the issues improves. The costs of reducing emissions and decarbonizing power supply appear daunting now, and will be even worse with delay. But the goals are achievable. For example, the European Climate Foundation Roadmap 2050 study uses existing technologies (those available today and those in late-stage development) and finds that transformation of the European power sector to a reliable, secure, and fully decarbonized supply is feasible and affordable.[7]

C. Major Challenges in Decarbonizing the Electric Sector

Achieving the global emissions reduction goal of 80 percent below 1990 levels is an enormous challenge. The electric sector will play a major role in achieving emissions reduction goals due to the volume of its emissions and the ability to substitute electricity for more polluting forms of energy use. It is the sector emitting the most GHGs, responsible for 41 percent of world CO_2 emissions, and its emissions come for the most part from large generating stations that are easier to regulate than innumerable dispersed sources (such as automobiles in the transportation sector).[8] Reducing emissions from the power sector, a large task in itself due to the sheer volume of emissions, will be made even more challenging due to trends in global energy production and use that will result in growth in demand for electricity. The International Energy Agency anticipates that electricity demand will grow more strongly than any other final form of energy, with energy growth in China leading the way. Trends affecting the electric sector include:

1) increasing electrification as many countries under development seek to improve their standard of living. Electrification may be a less-emitting option than current practice, and thus a contributor, not challenge, to global GHG reduction goals. It does, however, present a challenge to reducing emissions from the power sector; and
2) increasing electrification due to efforts to reduce the combustion of fossil fuels in the transportation and housing sectors. Again, electrification of transportation should assist in achieving global GHG reduction goals; however, it does present a challenge to decarbonizing the power sector.

The electric sector is traditionally composed of long-lived, capital-intensive resources with operating lives of 30 years, 50 years, or even more. As a result, change does not occur quickly. Some cost factors—such as natural gas prices, increased end-use energy efficiency that reduces pressure on electricity supply resources and enables retirement of old, infrequently used resources, and more stringent environmental regulations—are spurring a transition away from older, more carbon-intensive resources. It will not be sufficient merely to switch to greater use of natural gas, however, as its carbon content will prevent the electric sector from achieving 80-percent reductions in GHGs. At best, natural gas may be a short-term transition fuel between now and 2030 or 2040. In this context, the fact of lower natural gas prices is a double-edged sword, as lower prices speed the transition by making conversion less expensive, but lower gas prices are also likely to slow the transition from natural gas to renewables and other low-carbon resources. The net overall effect is unclear.

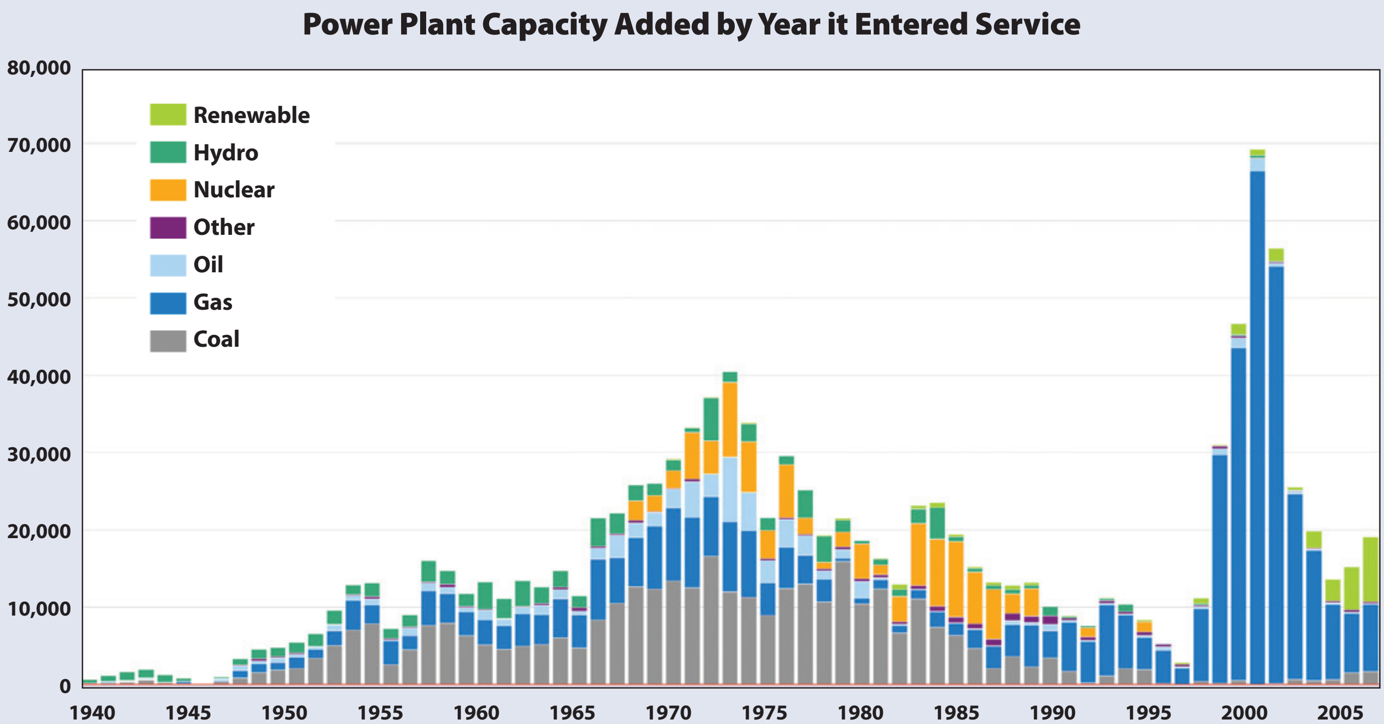
Aging electric power infrastructure in developed nations will require significant investment in the next decade. For example, in the United States more than 70 percent of the coal-fired capacity is more than 30 years old.[9] Turnover and investment in the electric sector provides an opportunity to replace carbon-intensive resources with low-

7 European Climate Foundation, 2010

8 International Energy Agency, 2011

9 Based on US Environmental Protection Agency data on Coal Unit Characteristics from 2009.

Figure 1



Source: CERES, et al., *Benchmarking Air Emissions of the 100 Largest Electric Power Producers in the United States*, http://www.ceres.org/Document.Doc?id=600, June 2010.

carbon resources. Similarly, investment opportunities in developing nations are enormous as those nations strive to electrify their economies. Both developed and developing nations are making crucial decisions of lasting import, as investment in high-emitting resources now will lock in carbon emissions for years to come. Figure 1 above shows power plant capacity additions over a span of more than 60 years in the US. The graphic helps to reveal the advanced age of most of the coal fleet, and the advancing age of nuclear fleets. Low natural gas prices combined with gains in technology and a supportive policy framework have, in the last 15 years, led to significantly increased natural gas combined cycle generation and investment in variable energy renewable generation.

Long-term transition to a low-carbon power sector will require technological innovation that results in the invention and commercialization of new, zero-carbon technologies and strategies, as well as policy strategies that steer investment away from carbon-intensive power production and toward low-carbon alternatives. Provision for aggressive research and development, which may accelerate commercialization of new technologies, is thus an essential component of a coordinated decarbonization strategy. Further, although some successful policies may develop serendipitously, successful outcomes are far more likely to develop expeditiously within the framework of an explicit plan that coordinates complementary policy strategies.

D. Purpose of this Paper

Achieving 80-percent emissions reductions from 1990 levels will require sustained and vigorous commitment to decarbonization of the electric sector. In light of this reality, the purpose of this paper is to present best practices in strategies for decarbonizing power supply.[10] The paper

10 This paper is one in a series of Global Power Best Practice reports from the Regulatory Assistance Project. Some topics, such as energy efficiency, renewables and clean energy technologies, demand integration, transmission, renewables integration in wholesale market, and others are covered in more detail in specific reports in this series.

highlights examples of best practices for technology research and development, and for policy initiatives to foster deployment of those technologies. It does not attempt to be an exhaustive catalog of such strategies nor of every instance of implementation of a particular strategy.

Section 3 of this paper discusses technologies that are available to form part of a decarbonization strategy, including reducing emissions from fossil-based resources through increased conversion efficiency and emissions capture, and the use of non-fossil resources such as renewables and nuclear power. Section 4 turns to the major policy strategies for discouraging the use of high carbon-emitting resources and encouraging low-carbon resources. Examples of policy strategies include creating a cost to emit carbon, improving resource planning, and implementing emissions or portfolio standards. Section 4 also discusses the impact on carbon emissions of non-carbon-focused environmental regulation. Section 5 examines policy strategies that support technological innovation as well as one model for funding investments in research and development focused on energy technology alternatives, and provides a brief overview of market issues associated with the integration of demand response. Section 6 presents our conclusions regarding best practices in strategies to decarbonize power supply, recognizing that each country's circumstances will affect which strategies are more suitable or effective for its particular circumstances, or the details of how a particular strategy is implemented.

3. Technology Strategies

Strategies for decarbonizing power supply through the use of technology include improving the efficiency of conversion at existing and new fossil-fired power plants (i.e., more power produced per unit of fuel used), implementing carbon capture and sequestration (CCS), and replacing fossil-fired generation with renewable and other low-carbon resources. Many of these technology strategies are under development, so the technologies are presented here, along with an overview of their current status. Policies that encourage development of certain technologies or groups of technologies are discussed in Sections 4 and 5.

Table 1

Assumed Plant Efficiencies and CO_2 Emissions[13]

	Subcritical	Supercritical	Ultrasupercritical	IGCC
Generation Efficiency (Higher Heating Value)[14]	34.3%	38.5%	43.3%	38.4%
CO_2 Emitted (g/kWh)	931	830	738	824

A. Increasing the Energy Efficiency of Conversion

Reductions in emissions of CO_2 can be achieved through new technologies that increase the operating efficiencies of new and existing coal plants by increasing the amount of energy produced from the same amount of fuel. New integrated-gasification combined-cycle (IGCC) and ultrasupercritical coal plants are being designed to operate at higher steam temperatures and pressures than the subcritical plants that are currently in operation, which reduces CO_2 emissions per unit of electrical output by improving the efficiency of the plants. In 2008, the average annual efficiency of the coal fleet in the United States was 32.5 percent.[11] IGCC plants around the world operate at efficiencies of 35.4 to 40.5 percent, and ultrasupercritical coal plants in Europe and Japan operate at efficiencies of 42 to 44 percent.[12] Table 1 shows the results of one study on the operating efficiencies and the CO_2 emissions associated with different coal combustion technologies in a hypothetical 500-megawatt-equivalent (MWe) coal plant. This plant is assumed to be burning Illinois #6 coal and operating as a baseload unit at a capacity factor of 85 percent.

Advanced coal plants constructed in the next seven to ten years are expected to have benchmark efficiencies of 46 percent.[15] Even small percentage gains in operating efficiencies can be important, as a one-percent increase in operating efficiency results in a two- to three-percent decrease in emissions of CO_2.[16] Denmark, Germany, and Japan have driven the development of advanced coal plant technologies in recent years,[17] but many future opportunities for advanced coal designs exist in other countries, as discussed in the next section. It has been estimated that an additional 45 gigawatts (GW) of new coal

11 National Energy Technology Laboratory, 2010

12 Beer, 2009

13 From Booras and Holt, 2004, as cited in Beer, 2009, p. 7

14 The heating value of coal is the amount of heat released during combustion. The higher heating value (HHV) assumes that all of the water in a combustion process is in a liquid state after a combustion process. The lower heating value (LHV), in contrast, assumes that the water component is in a vapor state after combustion. Values in the United States are typically expressed in terms of HHV, whereas values in Europe are expressed in terms of LHV.

15 Beer, 2009, p. 2

16 World Coal Association

17 World Coal Association

capacity will be constructed during the coming decade in the United States alone. The CO_2-e emissions over the lifetime of these coal units would be 700 million metric tons (MMT) less if ultrasupercritical technologies were used rather than subcritical technologies.[18]

Current Status and Efforts

According to the US Government Accountability Office, there are five IGCC plants in operation around the world, including two in the United States: the 262-megawatt (MW) Wabash River plant in Indiana and the 250-MW Polk Power Station in Florida.[19] A third, the Edwardsport plant, a 630-MW IGCC facility, is being built in Indiana and is scheduled to be completed in 2012.

The John W. Turk, Jr. plant in Arkansas is the only ultrasupercritical plant currently under construction in the United States. This 600-MW plant is also scheduled to be completed in 2012. A number of ultrasupercritical plants, ranging from 600 to more than 1,000 MW, have been built or are under construction in Europe and Asia, particularly in China. The International Energy Agency reports that there has been a surge in demand for supercritical and ultrasupercritical units of at least 600 MW, and that China "has since become the major world market for advanced coal-fired power plants with high-specification emission control systems."[20]

In its *National Action Plan on Climate Change,* the government of India has stated that it plans to retire inefficient coal-fired power plants while supporting the development of IGCC and supercritical coal technologies.[21] India's Central Electricity Authority is working with the Japan Coal Energy Center to identify its less efficient coal-fired plants and identify retrofits that would improve the plants' efficiencies.[22] India has also signed a Memorandum of Understanding (MOU) with the United States, entering into a strategic partnership focusing on power plant efficiency improvements as one of its many goals.[23] Existing power plants may be repowered with the new technologies described above. Power plant improvements will also increase efficiencies, and include the following examples as identified by the US National Energy Technology Laboratory:[24]

- Cleaning tubes and boilers;
- Maintaining instrumentation;
- Restoring seals;
- Removing deposits on turbine blades;
- Condenser maintenance programs;
- Decreasing excess oxygen to the boiler;
- Installing variable speed drivers for motors; and
- Pursuing opportunities for waste heat utilization for coal drying and using solar energy for feed water heating.

Regulatory Issues

Building advanced technology coal-fired power plants is not without its challenges. Low prices for coal and natural gas may make advanced coal technologies uneconomical. Low coal prices limit the incentive to build more efficient, but more expensive, coal units, and higher capital costs may not justify expected fuel savings. Also, if low natural gas prices persist, utilities may choose to build natural gas power plants to reduce CO_2 emissions rather than building advanced technology coal units, which can be a net gain in terms of CO_2 emissions but does not advance the market for new, very efficient coal technologies.[25]

Rather than construct an entirely new coal unit, it is also possible to retrofit existing coal plants with advanced technologies to achieve CO_2 emissions reductions. The National Energy Technology Laboratory has estimated that increasing the thermal efficiency of the existing coal fleet by ten percent over a five-year period could reduce CO_2-e emissions by 150 MMT annually.[26] Such retrofits may be of limited attractiveness for US plants, however, due to the prospect of triggering the Clean Air Act's New Source Review requirements. Those requirements may be triggered if efficiency improvements were to increase a

18 Beer, 2009, p. 2

19 United States Government Accountability Office, 2010

20 International Energy Agency, 2009

21 Prime Minister's Council on Climate Change, 2008; see also Bhaskar, 2010

22 Ministry of Economy, Trade and Industry of Japan and the Planning Commission of India, 2010

23 United States Agency for International Development and National Energy Technology Laboratories, 2010

24 Eisenhauer & Scheer, 2009

25 United States Government Accountability Office, 2010

26 Eisenhauer & Scheer, 2009

plant's run time and overall emissions, which could require the installation of additional pollution control equipment. Plant operators are optimistic that they would be able to work with the US Environmental Protection Agency (EPA) to manage these requirements.

Technologies that improve new and existing coal plant efficiency offer potential for near-term reductions in CO_2 emissions and are currently available commercially. There are limits in the amount of CO_2 reductions that efficiency technologies can achieve, however, and these technologies should be used as a supplement to other emissions reduction strategies.

B. Carbon Capture and Sequestration

CCS refers to a number of technologies that can be used to capture CO_2 from a point source such as a power plant, compress it, transport it by pipeline, and inject it deep underground for storage.[27] CCS is still in the development stages for application in the electric sector, and although skeptics believe that the technology will ultimately be infeasible, others believe it can play an important role in the portfolio of emissions reduction strategies. According to the International Energy Agency, "in order to reach the goal of stabilizing global emissions at 450 ppm by 2050, CCS will be necessary."[28]

Current Status and Efforts

Component parts of the CCS process are already used in industry, and there are a handful of integrated projects that are currently operating. CO_2 capture is used in natural gas extraction and processing to make "pipeline quality" natural gas, and also when making fertilizer and synthetic natural gas. Captured emissions have been injected underground and used for enhanced oil recovery (EOR) for more than three decades. To date, EOR projects have used more than 560 million tons of CO_2.[29] These efforts, however, have not been concerned with the issue of how permanent underground sequestration of the CO_2 ultimately will be. Although integrated projects exist in the natural gas processing and oil recovery industries, there are currently no large-scale, integrated CCS projects in the power generation sector. Pilot projects now underway are discussed next, and developers all over the globe have sought both public and private sources of funding to begin to implement larger-scale projects.

Pilot Projects

Several small-scale pilot projects have been or are currently under development in various parts of the world. The AEP Mountaineer Project in West Virginia became operational in 2009, and was the first CCS project to successfully incorporate all elements in the chain (capture, transport, injection, storage, and monitoring) at a coal-fired power plant in the United States. CO_2 was captured from a 20-MW slipstream of flue gas at the plant and was stored in deep saline aquifers at the site, 1.5 miles below ground. According to Alstom Power, the demonstration project achieved the following: capture rates from 75 to 90 percent; injection of 7,000 tons of CO_2 per month; and energy penalties within a few percent of the expected value – 15 to 18 percent of the output the plant would have had without the capture technology.[30,31] AEP planned to scale up the project to the commercial scale level of 235 MW at a cost of $670 million. The company applied for and received $334 million in federal stimulus funding to put toward the project, but on July 14, 2011, AEP announced that it was putting the project on hold, citing the uncertain status of US climate policy and the continued weak economy.[32]

Table 2 lists the pilot projects that are currently operating or in development around the world.

Although Table 2 shows only pilot projects, five larger-scale integrated CCS projects in the United States received funding from the US Department of Energy (DOE). Two were subsequently canceled or postponed, including the AEP Mountaineer project. The other three are proceeding, and include the following:

1. A 60-MW facility southwest of Houston, TX, owned by NRG. Construction is scheduled to begin in 2013;

27 World Resources Institute

28 International Energy Agency, 2009

29 National Coal Council, 2011

30 Power Engineering, 2011

31 Blakenship, 2008

32 AEP places carbon capture commercialization on hold, citing uncertain status of climate policy, weak economy. (2011, July 14). American Electric Power. Retrieved from http://www.aep.com/newsroom/newsreleases/?id=1704

Table 2

Pilot CCS Projects[33]

Project Name	Size (MW)	CO_2 Storage	Start Date	Location
SchwarzePumpe	30	Depleted Gas	2008	Germany
AEP Mountaineer	20	Saline	2009	West Virginia, USA
Lacq	35	Depleted Gas	2010	France
Puertollano	14	Recycled	2010	Spain
Brindisi	48	EOR	2011	Italy
Callide-A Oxy Fuel	30	Saline	2011	Australia
Plant Barry	25	EOR	2011	Alabama, USA
Ferrybridge	5	Depleted Oil	2012	United Kingdom
Mongstad	0.1 MT/y CO_2	Saline	2012	Norway
Belchatow	250	Saline	2014	Poland
Compostilla	30	Saline	2015	Spain

2. The Texas Clean Energy Project, a new 400-MW IGCC plant. Construction is scheduled to begin in the fall of 2012; and
3. Hydrogen Energy, a new 250-MW IGCC plant in California. Construction is scheduled to begin in 2012.

There are two other CCS projects being developed in Texas that did not receive DOE funding: the Trailblazer project, a new 600-MW supercritical unit, and the Sweeney Gasification project, a new 680-MW IGCC unit.

Eleven CCS proposals in the power generation sector applied to receive funding from the European Investment Bank in May 2011. It is expected that four to six large-scale CCS projects could be supported, and a decision on funding is expected in the second half of 2012. Additionally, four projects are under development in Australia, six projects are under development in China, two projects are under development in South Korea, and three projects are under development in the Middle East.[34]

Gaps in Knowledge

There are several challenges associated with moving CCS from pilot-scale projects to commercial scale. From a technologic perspective, component pieces must be scaled up and integrated to work together. There are still numerous "unknowns" associated with CCS at a large scale, including water consumption, groundwater contamination, leakage of CO_2 emissions, and the parasitic loads associated with operation of CCS systems. Parasitic loads—the energy generated by the coal unit that goes to operate the CCS system instead of to customers—may also have an effect on the reliability of individual power plants; if any component of the CCS system becomes unavailable (capture, transport, or sequestration), the plant may need to shut down in order to avoid emissions of CO_2 that can no longer be sequestered. Other sources of electricity would need to make up for the generation output of the power plant in the event of a shutdown, and also for the parasitic loads associated with CCS when in operation.

From a policy perspective, implementation of CCS projects also has its challenges. With respect to transport, if CCS is to be deployed across an entire country, it would likely require an extensive network of pipelines to move CO_2 from the point of capture to the point of sequestration. Load centers, ideal power plant locations, and geology suitable for sequestration will be congruent only by luck. Cost of installing new pipelines in the United States has been estimated to be $1.5 million per mile, and the process would require challenging land and environmental permits before construction could begin.[35] With respect to sequestration, ownership interest for a storage reservoir is influenced by different laws, depending on the reservoir type. If CO_2 is being injected into oil and gas reservoirs or coal seams, or is being used for EOR,

33 Massachusetts Institute of Technology, 2011

34 Global CCS Institute, 2011

35 National Coal Council, 2011

ownership determination is based on mineral law, and is divided into mineral and surface interests. If emissions are being injected in saline formations, determination is based on water law.[36] Property interests matter, as they affect the long-term liability associated with potentially harmful and costly releases of CO_2 (into the air or into groundwater) from storage reservoirs. Further complicating the issue is that ownership and liability varies from state to state.

Although there are some uncertainties surrounding CCS technology and policy, the greatest constraint on the development of CCS is the cost. The Pew Center on Global Climate Change notes that "cost uncertainty has held CCS development back in the US more than environmental concerns over carbon leaks, earthquakes, and contaminated water."[37] The policy environment in certain parts of the world affects the economics of CCS; without a carbon price signal, proponents of CCS have been moving investments in decarbonization to alternative technologies. Stable policy support combined with a carbon price signal would "give industry confidence to continue moving forward and invest in CCS. In turn, such investment would ensure continuing innovation which will ultimately help to drive down capital and operating costs."[38] Policies that affect the transition from traditional coal to CCS are discussed in the Policy Strategies sections of this paper.

C. Non-Fossil Resources

Replacement of existing coal, oil, and natural gas generation with non-fossil alternatives is very promising for achieving decarbonization. An overview of recent research on the cost, availability, and reliability of renewable resources, distributed generation, fuel cells, and nuclear generating technologies is presented in this section. Policies to encourage non-fossil resources are discussed in Section 4.

Renewable Energy

Renewable energy technologies include hydro, wind (both onshore and offshore), solar, geothermal, biomass, and ocean energy.[39] Biomass is the most-used renewable technology around the world, with hydropower following as the second-largest renewable source of energy. The number of wind and solar installations has grown rapidly between 2000 and 2008, with wind technologies experiencing a seven-fold increase in that time period and solar photovoltaic (PV) installations increasing 16-fold.[40] Renewable technologies made up 19 percent of electricity generation worldwide in 2008 and are expected to either stay constant at 19 percent or grow to as much as 33 percent of generation by 2035, depending on what policy choices are made.[41]

These technologies each have their own benefits and shortcomings. Biomass technologies use a variety of fuel sources, including forest residues, agricultural waste, wood chips, and landfill gas, each of which can be widely available in some areas. Because forests and agricultural crops absorb carbon as they grow, and because biomass introduces no long-term sequestered carbon into the atmosphere, biomass is considered by some to be a carbon-neutral technology over the entire fuel cycle. Some contest this view, however, on the basis that emissions from land use, processing, and transportation may exceed the carbon sequestered in biomass, thereby resulting in significant net emissions. Carbon-accounting for biomass depends on a number of variables, particularly the source of the biomass. For example, biomass sourced from existing natural forests may reduce standing carbon stock and contribute to atmospheric emissions, whereas biomass from wastes and residuals does not, and therefore can be considered closer to carbon neutral. Emissions of certain pollutants, such as particulates and volatile organic compounds (VOCs) may also be greater with biomass than fossil-fueled technologies in some cases.[42]

Hydropower is a mature technology, can be used to provide baseload power, and has very low operating costs, although capital costs are highly site specific. Opportunities for new hydropower projects are limited, however, because in some countries most of the suitable sites are already in use. Where new hydropower projects do get constructed, newly flooded reservoirs can produce large volumes of CO_2 and methane emissions as vegetation and soil organic

36 de Figueiredo, 2005

37 Gallucci, 2011

38 Global CCS Institute, 2011

39 Ocean energy includes power created from surface waves, tides, salinity, and ocean temperature differences.

40 International Energy Agency, 2010

41 International Energy Agency, 2010

42 Fisher, Jackson, & Biewald, 2012

matter decomposes. Newly flooded reservoirs also favor the production of methylmercury, as mercury can be converted from one form to another in surface waters.[43] Hydropower dams also cause problems for fish and other wildlife.

As mentioned previously, the number of wind and solar installations has grown substantially over the past decade. Despite this growth, these technologies face a challenge in that they are intermittent resources and are not continuously available to provide energy to the electric grid. When intermittent resources cannot be dispatched to meet energy demand, other resources must often be available to provide a reliable supply of electricity, depending on the load and source mix on the given grid and the specific technologies. A solar thermal plant, for example, can include molten salt thermal storage to provide a more base load type of resource, while electric storage, demand response, or hydropower energy banking can meet that need as well. Solar PV power can be distributed near load centers and is most available at time of peak demand in many areas, so backup resources may not be an issue. As the MW contributions of wind and solar technologies increases, upgrades to the transmission grid may be required to accommodate these resources. In some cases, new transmission lines must be built to move wind power from the best wind sites to load centers. This is especially true for offshore wind projects, where submarine cables must be installed in order to bring wind energy to shore.

Ocean energy technologies do not suffer from the problem of intermittency; however, these technologies are still in development. There are several pilot tidal projects operating in various countries, and a handful of commercial-scale ocean energy projects generating electricity. The Rance tidal power plant in France was the first project to be completed. It began operations in 1966 and has 240 MW of installed capacity. The Sihwa Lake Tidal Plant in South Korea is currently the largest tidal power installation in the world, with 254 MW of capacity. This plant was completed in 2011. The first and largest tidal site in North America is the Annapolis Royal Generating Station in Nova Scotia, which began operations in 1984 and has 20 MW of capacity.[44] South Korea is looking to become a leader in tidal power projects, with a proposed project near the islands of Ganghwa, Jangbong, and Yeongjong, with a project capacity of 1,320 MW. Construction would begin in 2017.[45] The first grid-tied tidal power turbine in the United States (5 MW) started operations in Maine in September, 2012.[46] Ocean projects generating power from surface waves, salinity, and ocean temperatures exist at the pilot scale, but no commercial-scale projects have yet begun operation.

What is common to all these technologies is that low fossil capital costs can present a barrier to deployment. Some renewable technologies are not yet cost-effective in the market and benefit from policies and financial incentives designed to increase the penetration of these renewables. Global demand for renewables has increased capital equipment prices in instances when there have been shortages of construction materials or equipment, but increased demand has also led to declining prices as technology innovations occur. Estimates of costs for some renewable technologies by global investment bank Lazard Company are shown in Table 3.

In addition to the technologies in Table 3, large solar PV projects are estimated by Lazard to have installed costs between \$3.50 and \$3.75 per Watt (direct current delivered by the PV cells) and between \$4.22 and \$4.52 per Watt (alternating current) after conversion for use on the grid.[47] Performance (and return on investment) depends on meteorologic conditions in the area where the project is installed. This can vary greatly, making generalizations about delivered costs difficult.

The greatest amounts of existing, installed renewable energy resources (other than hydropower) are found in the United States and the European Union. Over the past several years, China has also emerged as a leader in installing wind turbines and PV technologies, as well as being one of the major suppliers of these technologies.[48]

43 United States Geological Survey, 2000

44 Daowoo E&C.

45 Balboa, 2009

46 See Ocean Renewable Power Company, http://www.orpc.co/content.aspx?p=h3jCHHn6gcg%3d

47 Lazard, Ltd., 2010

48 International Energy Agency, 2010

Table 3

Costs of Certain Renewable Technologies (2010$)[49]

Cost Factors	Onshore Wind	Offshore Wind	Direct Fired Biomass	Geothermal	Concentrating Solar
Installed Cost ($/kW)	$2,276-2,630	$3,793-5,058	$3,035-4,046	$4,653-7,333	$5,000-5,300
Fixed O&M ($/kW-y)	$61.00	$61.00-101.00	$96.09	$0.00	$66.00
Variable O&M ($/kW-y)	$0.00	$13.15-18.21	$15.17	$30.34-40.46	$0.00
Capacity Factor (%)	30-40	32-45	85	80-90	26-29
Energy Cost ($/MWh)	$86-131	$134-258	$92-148	$96-160	$161-188*
Fuel Cost ($/mmBtu)	N/A	N/A	$1.01-3.34	N/A	N/A

**Includes the United States federal investment tax credit. Energy cost ($/MWh) will be higher in the absence of this tax credit.*

Distributed Generation (Including Combined Heat and Power)

Distributed generation technologies are typically small generation sources located at the same site where some or all of the electricity generated is being used. On-site generating resources range in size from a few kilowatts (kW) to ten MW. Distributed generation resources can take many forms, including solar PV, small wind turbines, fuel cells, fossil-fueled generating units, and combined heat and power (CHP) systems. In CHP systems, heat engines or power stations simultaneously generate both electricity and useful heat. Waste heat from electric generators is used for space or water heating, process heating, or air conditioning. Distributed resources, especially renewable and CHP installations, may have lower emissions of carbon dioxide overall than power from traditional fossil-fired central generating stations.

Because distributed resources generate power at or near where it is being used, the amount of energy lost from delivering electricity over long distances is greatly reduced. Further, costs of constructing transmission and distribution lines may be avoided. The elimination of most if not all transmission and distribution costs may make some installations more attractive than remote central station generation. On the other hand, large generating units are often less expensive for a given total capacity due to economies of scale that can be achieved during construction.

Fuel Cells

Fuel cells convert chemical energy in a fuel, such as hydrogen or natural gas, into electricity without combustion through a chemical reaction with oxygen or another oxidizing agent, producing water and heat as its byproducts. Fuel cells can be built in varying sizes, from one kW to hundreds of megawatts, and can achieve efficiencies of up to 80 percent when waste heat is captured for use along with the electricity produced, as in CHP applications. Some of the barriers to fuel cell commercialization include cost, durability, size, weight, and thermal and water management.[50] On the other hand, fuel cells can provide extremely reliable and stable power, which is highly valued by data centers and similar critical applications. The accepted price point at which fuel cell systems can be competitive with conventional technologies is quite high: $1,000/kW for initial applications and $400-750/kW for wider commercialization.[51]

Nuclear

Nuclear power sources provide approximately 14 percent of the electricity generated in the world:[52] 20 percent of the electricity generated in the United States, 28 percent in the European Union,[53] and just over 4 percent in China.[54] As of early 2011, there are 440 nuclear reactors

49 Lazard, Ltd., 2010

50 United States Department of Energy, 2011

51 United States Department of Energy, 2011

52 Electric Power Research Institute, 2011

53 European Commission, 2011

54 Jervey, 2011

in operation in 29 different countries, and 65 new reactors under construction in 15 countries.[55] Nuclear plants can be operated at very high capacity factors for a significant number of years, and although they are quite expensive to construct, their operating costs are relatively low compared to comparable fossil fuel generating units. They typically operate as baseload units, but current and some planned designs are subject to multiweek shutdowns for refueling, scheduled maintenance, and sometimes unscheduled outages. This makes large amounts of replacement capacity and energy necessary. Table 4 shows an estimate of the costs associated with construction of a new nuclear plant.

Although new, advanced nuclear reactors are planned to be more standardized in design than existing reactors—and are expected by some to have significant performance and safety improvements—nuclear power plant construction is still a very complicated process with numerous unknowns that can negatively impact plant economics. Storage of nuclear waste also has many unknowns. There are currently several ways in which nuclear waste can be stored, including wet pools, dry containers, and underground, but these methods are temporary. A long-term waste-storage solution has yet to be determined for most countries, and could come to represent the single biggest expense of the nuclear power industry.

Table 4

Cost Estimate for a New Nuclear Plant[56]

Cost Factors	Costs
Installed Cost ($/kW)	$5,447-8,293
Fixed O&M ($/kW-y)	$12.95
Variable O&M ($/kW-y)	$0.00
Capacity Factor (%)	90%
Energy Cost ($/MWh)	$78-115
Fuel Cost ($/mmBtu)	$0.51
Waste Storage ($/kWh)	$0.001

Note: The figure for waste storage represents the fee currently charged by the US DOE to commercial reactor operators and does not necessarily represent the final cost to society for interim or permanent disposal of radioactive waste.

55 Electric Power Research Institute, 2011

56 Lazard, Ltd., 2010, and Nuclear Energy Institute, 2011

4. Policy Strategies Discouraging Fossil Fuel Use

Fossil fuel consumption is responsible for 57 percent of global GHG emissions.[57] Electricity supply contributes 41 percent of the emissions from the consumption of fossil fuel.[58] Energy efficiency, reducing the consumption of electricity necessary to provide energy services such as heating, cooling, lighting, and operation of appliances, is widely regarded as the most promising technology approach to reducing GHG emissions associated with the electric sector. But even with aggressive energy efficiency, it will be necessary to change the emissions profile of the electric sector as part of efforts to achieve scientifically based GHG emissions reduction targets. This paper focuses on strategies for reducing carbon emissions from the power supply sector rather than examining demand-side efficiency. A very important component of any effort to decarbonize the electricity supply is to reduce reliance on fossil fuels. This section provides an overview of certain policy strategies for discouraging fossil fuel use and for encouraging development and deployment of the technical strategies covered in the preceding section. Those policy strategies include putting a price on carbon emissions, adoption of policies targeting carbon intensity measures, resource planning strategies, establishing emissions standards for contracts or supply portfolios, and regulation of environmental impacts other than GHGs. As will be seen, no single approach will provide sufficient decarbonization potential to achieve scientifically based emissions reduction targets.

A. Carbon Price

A mechanism to price the emissions contributing to climate change is an important element in any effort to reduce GHG emissions. Carbon pricing will be most effective when combined with other policies to increase the use of less carbon-intensive resources in the electric sector, such as those discussed in subsequent sections. Policies that provide a real or implicit price of carbon internalize the cost of carbon emissions and can thus make renewables and other low-carbon resources cost-competitive with other energy sources. This, in turn, creates incentives for producers and consumers to invest in low-GHG products, technologies, and processes. Policies that provide a carbon price can also serve as a source of revenue for funding low-carbon technologies and programs (as does the Regional Greenhouse Gas Initiative in the northeastern United States), thus facilitating the transition to a carbon-constrained world.

Emissions caps and taxes are the two primary policy tools for placing a price on carbon emissions, and can be applied to a specific sector or economy-wide. A tax provides price certainty, although the resulting quantity of emissions reduced may vary. Conversely, a cap provides certainty on the quantity of emissions that will occur, but prices (and costs to emitters and consumers) are difficult to predict. Although the concepts behind both caps and taxes are straightforward, experience in designing and implementing such programs demonstrates the critical importance of details in creating an effective program with a meaningful price signal. In some instances, these mechanisms work together in tandem (e.g., the carbon floor price in the United Kingdom, and the tax on sectors not covered by the cap in France and Sweden) or sequentially (e.g., the Australian tax followed by a cap and tradable permits). Another mechanism for introducing a price on carbon emissions in the power sector is the use of a carbon adder in evaluating supply resources. This mechanism is discussed in the section on resource planning.

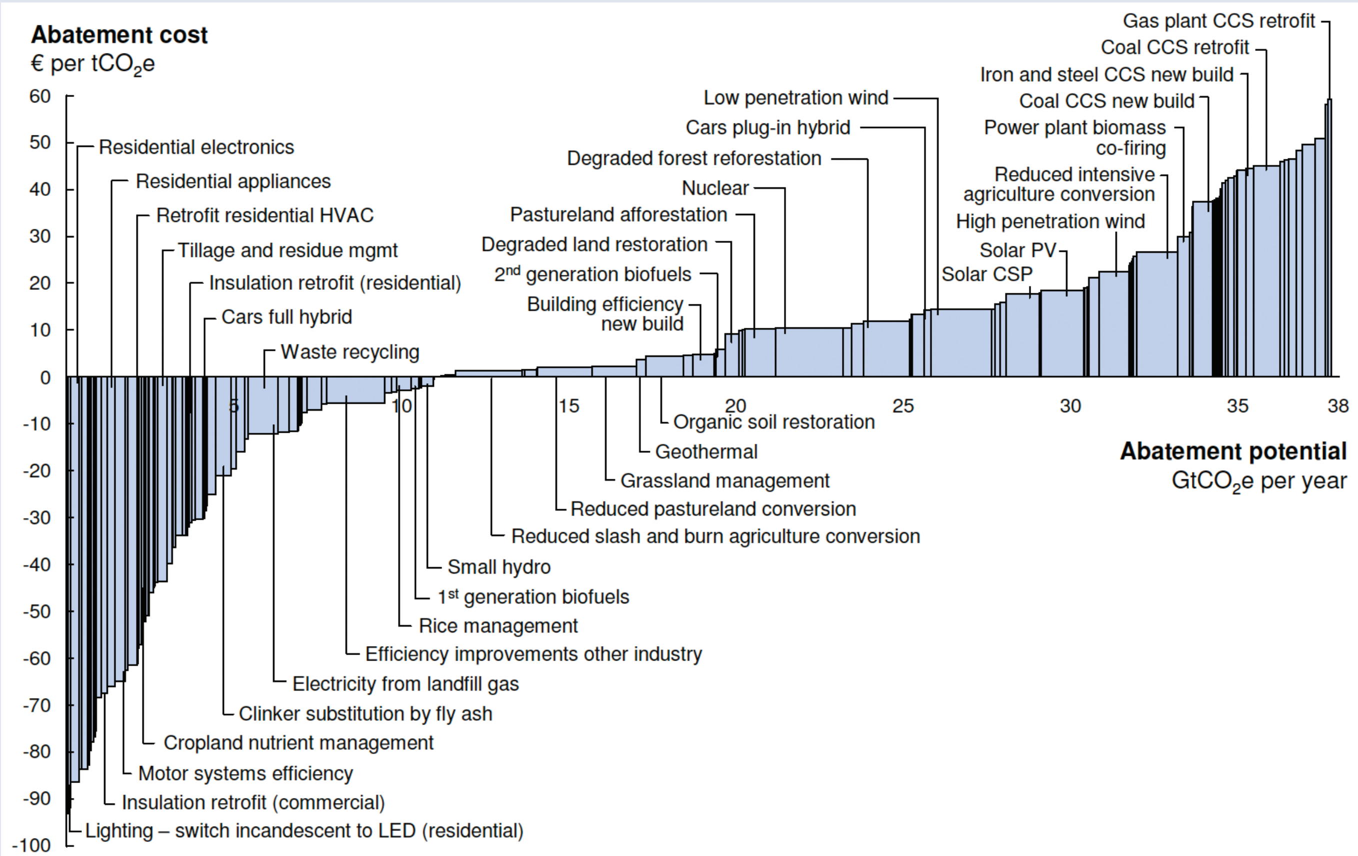
IPCC analyses suggest that carbon prices of \$20 to \$80 per ton CO_2-e, sustained or increased over decades, could eliminate most carbon emissions from power generation

57 International Energy Agency, 2011

58 Rogner, Zhou, Bradley, Crabbe, Edenhofer, Hare (Australia), Kuijpers, Yamaguchi, 2007

Figure 2

Global GHG Abatement Cost Curve Beyond Business-as-usual — 2030



Note: The curve presents an estimate of the maximum potential of all GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

and make many mitigation strategies financially attractive.[59] Although this range of prices currently seems politically infeasible in many countries, such as the United States, it is not necessary or even prudent to rely on a pricing mechanism alone. A carbon pricing policy can be combined with complementary policies to lower the cost of achieving a given level of reduction. This approach is discussed below in the section on carbon cap-and-trade programs and further in the Conclusion.

Carbon Tax

A carbon tax is a tax levied on the carbon content of fuels. A carbon tax incorporates the cost of emissions, which were previously unpriced, into the cost of a fuel or energy source that is faced by market participants. It thus affects the relative economics of different fuels or energy sources, improving the competitiveness of low-emission sources. Advantages of carbon taxes include the fact that taxation offers flexibility to affected sources in determining their response to the tax and encourages a range of technical and institutional abatement options. It is relatively easy to apply to small and dispersed resources as well as large point sources, requiring little more in the way of infrastructure and bureaucracy than a simple sales tax. A tax provides transparency and cost certainty, and creates a strong and continuing incentive to innovate as a mechanism for reducing emissions and associated tax

59 IPCC Fourth Assessment Report, 2007

payments. A carbon tax also generates revenue that may be used to reduce collection of other taxes, thus making the carbon tax optionally revenue neutral. A portion of the tax revenue may also be invested in low-carbon resources to facilitate the transition to a low-carbon economy.

Current Status and Efforts

Several countries are currently implementing carbon taxes, although not all of them apply to electricity. In the European Union, countries' carbon tax implementation is affected by their participation in the EU's Emissions Trading System (ETS). For example, Scandinavian countries adopted carbon taxes in the early 1990s, but now the electric sectors in those countries primarily include a price on carbon through the EU's ETS. Although most taxation activity is in the European Union, the US city of Boulder, Colorado, has also adopted a carbon tax on retail consumption of electricity, the first implementation of carbon taxation in that country.[60]

Finland introduced a carbon tax in 1990; it was the first country to do so. Since 1997, fuels for electricity production have not been taxed; however, there is an output tax on electricity, which falls into two classes: a lower rate for industry and greenhouse cultivation, and a higher rate for households and the service sector. Subsidies are available for renewable energy sources (e.g., wind, small-scale hydropower, and recycled fuels) to improve their competitiveness and to partly compensate for the tax.[61]

Denmark's CO_2 tax became effective in 1992. Fuels for electricity generation are exempt from the CO_2 tax; emissions from the combustion of fuels used for electricity generation are instead affected by a CO_2 tax on electricity consumption.

Sweden and Norway both imposed a carbon tax in 1991; however, neither a carbon tax nor an energy tax is applied to electricity production. Norway's was initially set at a high level, which led to exemptions for the majority of industries due to political pressure. Norway joined the European cap-and-trade program in 2008.[62]

In British Columbia (BC), Canada, a carbon tax became effective July 1, 2008. The tax applies to all emissions from fossil fuel combustion in BC captured in Environment Canada's National Inventory Report, and includes fossil fuels used for transportation and in all industries, as well as fuel to create heat for households and industrial processes. The initial rate was $10/tonne of GHG emissions, and was set to increase by $5/tonne each year to $30/tonne by 2012. The tax is revenue neutral, with 100 percent of revenues from the tax being returned to citizens through tax reductions and tax credits.[63] Quebec has a hydrocarbon fuels tax on coal, oil, and natural gas; the tax rate is fairly low and revenues are put into a Green Fund rather than into tax reductions and tax credits.

Some EU countries are implementing a carbon tax as a complement to their participation in the EU ETS. For example, the United Kingdom began a Climate Change Levy on electricity, coal, and natural gas in 2001. More recently it has instituted a tax that would serve as a floor on carbon prices. The Chancellor of the Exchequer announced in Budget 2011 that the carbon floor price will start at around £16 per tonne of carbon dioxide in 2013 and move to a target price of £30 per tonne in 2020.[64] The purpose of this tax would be to provide some price support and cost certainty surrounding the cost of emitting carbon, in order to provide an incentive for investment in low-carbon resources. There is some debate on its effectiveness in this regard, as it is part of the tax system and thus subject to political factors.[65] In 1998, Germany broadened its energy taxes as part of a so-called "ecological tax reform."

Australia is implementing a carbon tax as a transition mechanism to market-based trading. The tax plan, which focuses on the largest 300 polluters, is the central element in Australia's multifaceted Clean Energy Plan from 2011. The Plan includes provisions for funding clean energy, financing coal plant retirements and retrofits, reducing taxes on low-income households, maintaining energy security, improving energy efficiency, and more.[66] More

60 See Boulder's Climate Action Plan at: http://www.bouldercolorado.gov/index.php?option=com_content&view=article&id=15356&Itemid=396

61 Finnish Ministry of the Environment, 2011

62 Pew Center on Global Climate Change, 2008

63 Ministry of Finance, British Columbia, 2008

64 Information on the carbon floor price is available at HM Treasury website, see http://www.hm-treasury.gov.uk/consult_carbon_price_support.htm

65 Climate Change Capital, 2011

66 Australia's Clean Energy Future Plan, 2011. See also Crossley, 2012

than half of the revenues would be offset by tax breaks for lower-income households. Legislation passed by both houses of Parliament includes a carbon tax on large polluters starting in July 2012 (beginning at $24/tonne CO_2), which is scheduled to transition to a market-based trading mechanism in 2015.[67] Modeling done for the Treasury shows that initial emission reductions would be gradual in the electric sector, with most reductions prior to 2020 being attributable to the renewable energy target. After 2020, however, the modeling showed significant cuts to emissions in the electric sector with clean coal, gas, and geothermal power becoming dominant.[68] In the original version of the Australian Clean Energy Future Plan, coal-fired generators with emissions intensity greater than 1.2 tonne CO_2-e per MWh of electricity on an "as generated' basis could apply for inclusion in a government-funded program to encourage the early retirement of approximately 2,000 MW of brown-coal generator capacity. In early September 2012, however, the Australian Government announced that it has not been able to reach agreement with the owners of any of the emissions-intensive power stations on a price for buying out and shutting down a power station. Consequently the buy-out program will not proceed. However, all power stations with emissions intensity above 1.0 tonne CO_2-e per MWh may be eligible for free permits and loans to purchase future vintage permits. The government has also established an Energy Security Fund to mitigate energy security issues and to reduce the financial impact of the carbon tax on high-emission generation facilities. The Fund will provide loans for any power stations that are not able to meet their loan covenants with banks because the book value of their assets has been reduced as a result of the implementation of the carbon tax.[69]

Some carbon or fuel taxes are designed primarily to generate revenue. In 2010, India announced a levy on coal at the rate of 50 rupees ($1 USD) per ton. The tax applies to domestically produced and imported coal, with tax revenues going to the National Clean Energy Fund. The Fund will support research, new projects in clean energy technologies, and environmental remediation programs. However, some policy leaders in India are also looking at the development of the carbon tax program in Australia as a possible source of ideas for India in meeting its emissions intensity reduction goals.[70]

China imposes resource taxes on fuel sources (the tax on coal is collected on a volume basis), and funds are used primarily for development projects (roads and railways, as well as a wind farm and a nuclear power plant).[71] Although this tax is not specifically driven by climate change concerns, such a tax could potentially affect the relative economics of coal-fired power generation and thus affect emissions of GHGs from combustion of coal. It is important to note that the electric sector in China is not primarily driven by, or governed by, market forces currently; therefore, the price signal of a tax on coal may be obscured or lost. However, China is slowly trying to introduce some market elements into the electric sector.

Lessons Learned and Gaps in Knowledge

Carbon taxes can be used to address the failure of markets to take environmental impacts into account. The Organization for Economic Co-operation and Development (OECD) has identified the following among important design characteristics for an effective environmental tax:[72]

- Taxes should be levied as directly as possible on the pollutant or polluting behavior, with few if any exceptions, because increasing the market cost of polluting activities generally helps to incentivize a full range of abatement options compared with having no market cost at all;
- The scope of the tax should be as broad, ideally, as the scope of the impact;
- The tax rate should be commensurate with the environmental damage;
- The tax must be credible and its rate predictable in order to motivate environmental improvements; and
- For greatest impact, environmental taxes should be paired with complementary policy instruments that support energy efficiency and cleaner supply technologies.

67 Australia's lower house passes carbon tax, 2011; Australia senate passes carbon tax, 2011

68 Taylor, 2011

69 Crossley, 2012

70 Global Climate: India Says Australian Carbon Tax a 'Useful Idea,' 2011

71 China to Extend Oil, Gas Resource Tax Nationwide Next Month, 2011

72 OECD, 2011

Many of these conditions have not yet been met, because taxes have been applied in specific countries rather than on the same scale as GHG emissions impacts, have included many exemptions, and have been at a fairly low tax rate (insufficient to meaningfully change the economics of different resource options). For the most part, carbon taxes to date have remained fairly low—ranging for industries from near zero to about 25 euro/ton CO_2 in Sweden and Finland; however, even those tax rates appear to have caused reductions in fuel consumption and GHG emissions (with higher tax rates showing higher reductions).[73] Implementation of the Australian tax plan will provide further insight into the development and implementation of carbon tax approaches.

Carbon Cap

A cap-and-trade system puts a price on carbon by setting limits on the quantity of emissions that polluters may produce, and by establishing a system of tradable allowances that in total allow emissions up to the level of the cap. A cap-and-trade system is more flexible than command-and-control approaches that impose a technology standard or a unit-specific performance standard. It is flexible also because it allows various compliance options, including purchase of allowances, installation of emissions controls, or emissions avoidance through retirement or fuel switching. The better performers—those with lower emissions—benefit economically from their performance, whereas higher-emitting sources can determine the cheapest way to comply with requirements. Important issues in the design of a cap-and-trade system include establishing an appropriate cap level that will result in a meaningful carbon price and result in emissions reductions; determining how to distribute emissions rights under the cap; deciding what to do with any proceeds if allowances are distributed through auction; minimizing emissions increases from adjacent uncapped geographic areas (i.e., “leakage”); enhancing the cost-effectiveness of the cap-and-trade policy through implementation of complementary policies, and design issues such as credit for early reductions, banking and borrowing of allowances, and enforcement. Many of these issues are discussed below in the context of specific implementation efforts.

Current Status and Efforts

A few carbon cap-and-trade programs have been implemented in different countries and others are under development. The EU ETS, launched in 2005, is the first cap-and-trade system to cover GHG emissions. It now operates in 30 countries and covers CO_2 emissions from some 11,000 power plants as well as other key emission sources, such as oil refineries, iron and steel works, and manufacturing sources (cement, glass, lime, and others).[74] The program addresses almost half of the European Union’s CO_2 emissions and 40 percent of its total GHG emissions. In 2020, emissions under the cap will be 21 percent lower than they were in 2005.

Certain implementation and design issues have arisen since the program began. The first phase, from 2005 to 2007, was a learning phase during which carbon prices remained very low due to over-allocation of allowances, and some producers reaped windfall profits due to the free allocation of allowances to covered sources.[75] The second phase, from 2008 to 2012, builds on the first phase, broadens the industries covered by the trading system, and allows up to ten percent of allowances to be auctioned. For the third phase, beginning in 2013, ETS is moving to auctioning allowances. Although the move to auctions is a positive step, there can be a disconnect between the source of the revenues and the use of the revenues. Auction revenues can be treated like tax revenues and used by governments for purposes that have nothing to do with climate. Other revisions for the third period include a more ambitious, European Union-wide cap on emissions and reduced access to project credits from outside the European Union. Combined, these modifications should bring greater emissions reductions, greater certainty, and more predictable market conditions.

Although EU emissions credits have been trading at low to medium prices, there is some evidence that prices will increase in the coming years. Bloomberg New Energy Finance analyzed the costs of meeting emissions targets in the EU ETS. It determined that current allowance

73 Andersen, 2010

74 Information on the EU ETS is available from the European Commission at http://ec.europa.eu/clima/policies/ets/index_en.htm

75 Ellerman & Joskow, 2008

surpluses will give way to shortfalls after 2020, leading to significantly higher prices—on the order of 60 to 90 euros per tonne of CO_2.[76] Under the EU ETS, individual countries are able to set aside allowances for new entrants; however, because the French reserve appears too small to cover new entrants, the government is considering taxing entities covered under the EU ETS in France (based on revenues) to raise funds to purchase the necessary emissions allowances on the open market.[77]

The other major, albeit smaller, cap-and-trade program was adopted in the northeast region of the United States. The Regional Greenhouse Gas Initiative (RGGI) is an effort of ten northeast and mid-Atlantic states to limit GHG emissions, and is the first market-based CO_2 emissions reduction program in the United States.[78] Participating states have agreed to a mandatory cap on CO_2 emissions from the power sector, with the goal of achieving a ten-percent reduction in these emissions from 2009 to 2018.[79]

The RGGI program was developed over the course of several years beginning in 2003.[80] The states adopted an MOU in December 2005, wherein they agreed to auction a portion of allowances and use the proceeds for consumer benefit or strategic energy purposes, including funding state programs that promote energy efficiency and renewable resources.[81] The states also collectively developed a Model Rule in 2006 that served as the foundation for each state's CO_2 Budget Trading Program.

Taken together, the states' CO_2 Budget Trading Programs function to create a regional market for carbon emissions. The states have collectively auctioned approximately 90 percent of the program's CO_2 allowances. Auctions are conducted by RGGI, Inc.—a nonprofit entity established by the states to administer the program—and are independently monitored by a consulting economics firm. The first auction occurred on September 25, 2008, and the first compliance period began on January 1, 2009. Allowances through the first 13 auctions have generated approximately $900 million in revenue for the ten participating states.

The signature element of the RGGI program is the auction of RGGI allowances and use of auction proceeds for consumer benefit, particularly in those states that use auction proceeds to augment funding of energy efficiency programs. Initial analysis of the RGGI program indicates that a cap-and-trade program that simply relies on a price signal and market effects to achieve emissions reductions is likely to have higher overall costs than one that incorporates energy efficiency investments as an integral program component. Integrating energy efficiency into the program design can achieve carbon reductions at much lower cost.[82] For RGGI states with electric energy efficiency programs, the costs of reducing carbon emissions range from approximately a negative $53 to negative $100 per (short) ton of CO_2, with a weighted average cost of negative $73 per ton, indicating that the benefits of the efficiency investments far exceed initial costs.[83]

As for its overall economic impact, the RGGI program has produced $1.3 billion in energy savings to consumers, and $1.6 billion in growth in the region. Using the allowance proceeds to fund energy efficiency provides economic benefits in two ways: job creation in the efficiency industry, and electricity cost savings as consumers spend less on their electricity bills. Overall the RGGI program has produced greater economic growth in each of the ten states participating than would have occurred without a carbon price.[84]

---

76 Emissions are Under-Priced in Europe, 2011

77 France May Earn 200 Million Euros From Planned Carbon Tax, 2011

78 Information on the RGGI program, including history, important documents, and auction results is available on the RGGI Inc website at www.rggi.org

79 Currently emissions are capped at 188 million tons per year for the fossil-fueled plants under the RGGI cap. The cap on emissions starts to decrease in 2015, and will be approximately 169 million tons by 2018, a ten-percent reduction.

80 The ten states are: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Political considerations led New Jersey to announce that it will not participate in RGGI past 2011.

81 Under RGGI, one allowance represents one short ton of CO2. The portion allocated to energy efficiency varies state to state, but across the ten states up to 55 percent of the proceeds of auctions one through six were planned for energy efficiency. RGGI Auction Fact Sheet is available at http://www.rggi.org/docs/RGGI_Auctions_in_Brief.pdf

82 Chang, White, Johnston, & Biewald, 2010

83 Idem.

84 Hibbard, Tierney, Okie, & Darling, 2011

Despite initial concerns over potential for emissions leakage associated with the RGGI program, recent analysis by the Independent System Operator in New York indicates that the price of RGGI compliance did not have a statistically significant relationship with CO_2 emissions in Pennsylvania (an adjacent non-RGGI state).[85] Discussions are underway to extend coverage to imported sources of electricity.

California is currently developing a cap-and-trade program for the state, as well as working on a regional cap-and-trade program through the Western Climate Initiative. State law AB 32 identified a cap-and-trade program as one of the strategies to meet California's goal of reducing GHG emissions to 1990 levels by the year 2020, and ultimately achieving an 80-percent reduction from 1990 levels by 2050. Despite initial participation in the Western Climate Initiative by multiple western states and Canadian provinces, California is now the only US state participating.

One of the innovations incorporated into the program design is the application of its requirements to "First Jurisdictional Deliverers" of electricity in order to address emissions leakage issues, and to level the playing field between in-state electricity producers and those importing electricity into California. Briefly, electricity imports are subject to the cap-and-trade program, and there will be a compliance obligation on the entity that first delivers power into the California power grid.[86] The California Air Resources Board (CARB) is working with stakeholders to design a California cap-and-trade program that is enforceable and meets the requirements of AB 32.[87] The cap-and-trade regulation was anticipated to begin in 2012; however, CARB Chairman Mary Nichols announced in June 2011 that implementation of the regulation would not commence until 2013.

CARB's development and economic analysis of its plan for achieving the state's long-term emissions reduction goal provides an example of how a carbon price can be effectively combined with complementary programs to achieve an emissions goal. California's long-term goal for 2050 is to reduce its GHG emissions to 80 percent below 1990 levels. Its implementation plan, called a Scoping Plan, includes:

- expanding and strengthening existing energy efficiency programs as well as the standards that apply to buildings and appliances;
- achieving a statewide renewable-energy contribution of 33 percent;
- developing a California cap-and-trade program;
- establishing targets for transportation-related GHG emissions for regions throughout California and pursuing policies and incentives to achieve those targets; and
- adopting and implementing measures that were already in progress, including California's clean-car standards, goods-movement measures, and Low Carbon Fuel Standards.

The combination of a cap-and-trade program and complementary measures is intended to achieve cost-effective reduction in the short and medium terms, while accelerating the necessary transition to the low-carbon economy required for meeting the 2050 target. According to CARB:

> *By motivating investments in emissions reductions that would not be undertaken in response to price alone, complementary policies reduce the demand for allowances, thereby lowering their market price. This effect is true regardless of whether individual complementary policies generate net savings (that is, when fuel savings exceed capital costs) or have positive per-ton abatement costs that exceed the allowance price.*[88]

In its analysis of the Scoping Plan, CARB determined that with the combination of a cap and complementary strategies, 80 percent of overall emissions reductions derive from complementary programs.

Other nations have adopted or are exploring cap-and-trade mechanisms. New Zealand adopted a mandatory multisector emissions trading system in 2008 in order to meet New Zealand's commitments under the Kyoto Protocol.[89] The ETS currently covers emissions from

85 Gallagher, 2011

86 Singh, 2011

87 Information is available from CARB at http://arb.ca.gov/cc/capandtrade/capandtrade.htm

88 California Air Resources Board, 2010

89 Information on New Zealand's ETS is available from the Government of New Zealand at http://www.climatechange.govt.nz/emissions-trading-scheme/

forestry, stationary energy, industrial processes, and liquid fossil fuels, which are collectively responsible for roughly 50 percent of New Zealand's emissions. The energy sector became part of the trading system in 2010, and compliance obligations are primarily imposed on the basis of fuel supply (rather than electricity generation). For example, some of the specific activities that are included in the ETS are mining coal or natural gas and importing coal or natural gas. It is important to note that 65 percent of New Zealand's electricity comes from renewable energy sources (primarily hydro).

Japan has adopted a voluntary system.[90] China is exploring a cap-and-trade mechanism for pollution rights, although details are difficult to discern.[91] Development of a national cap-and-trade system for pollution is anticipated to begin with pilot programs in certain locations in China.[92] One central government policy organization, the Development Research Centre (DRC) of the State Council, has proposed imposing carbon caps on 10,000 major energy users, covering 40 percent of the country's energy-related carbon emissions. The proposal suggests that all Chinese companies using more than 80,000 or 100,000 tonnes of coal per year should be covered by a national ETS, and smaller companies could be included. These pilot schemes would either discontinue when a national scheme is launched or run in parallel with the national scheme. The DRC said an ETS should set absolute CO_2 caps on participants reflecting China's target to improve its carbon intensity 17 percent by 2015 compared to 2010 levels, and improve its energy intensity 16 percent over the same time period.[93]

Lessons Learned, Gaps in Knowledge, and Policy Directions

Implementation of cap-and-trade programs in Europe and the northeastern states of the United States has begun to provide important experience with cap-and-trade as a GHG reduction strategy for the electric sector. Experience with carbon cap-and-trade programs has provided several insights. Most important, efforts to discourage the use of carbon-intensive resources and encourage alternatives are approaches that complement each other. Complementary policies that reduce the cost of achieving emissions-reduction goals under the cap are able to spur emissions reductions from activities that are not covered or are not sufficiently incentivized by an established carbon price mechanism.

At a program design level, the experiences of both the European Union and the RGGI programs demonstrate the importance of getting the cap and the baseline right, in a fashion that results in a carbon price that will affect operational and investment decisions in the electric sector. The emissions limit should reflect actual emissions levels in order to create a clear and lasting incentive to reduce emissions.

Auctioning allowances, instead of distributing them for free to polluters, has emerged as a key component in an effective carbon cap mechanism. Auctioning creates a level playing field for program participants as well as an important funding source for complementary policies, such as those that promote energy efficiency and renewables—programs that lower the overall program price and provide economic benefits in the region in which it operates.

The absence of a comprehensive program covering all countries raises certain issues of coordination and the potential for a program in one region to cause greater emissions in an adjacent region that is not covered by a cap (i.e., "leakage"). It is important to link separate climate programs as much as possible to enhance environmental outcomes and increase the market size, thereby achieving greater economic benefits.

Thus far, emissions caps have been applied to emissions sources, but another option that has emerged is a "load-based" cap-and-trade program. A load-based cap-and-trade program would place a cap on absolute emissions related to all electricity use being served by an electric supplier (whether it owns generation or not). This policy creates a requirement for an electric company to lower the carbon content of its portfolio, and also sends a market signal to generators that low-emitting generation is a valuable commodity. This policy can readily accommodate other market-based compliance approaches available to companies (e.g., purchasing low-emitting power on

90 New Zealand Climate Change Information, 2011

91 National Development and Reform Commission, 2011. Also, China Aims to Unify Carbon Trading Platform by 2015, News Says, 2011

92 Lewis, 2011

93 Emissions trading system significant to green growth, 2001. Also Chen, 2011

the wholesale market, investing in energy efficiency and other demand-side management resources, or purchasing emissions allowances from other companies if it is economic to do so). The key features of this policy are similar to key features of a supply-side cap: (1) setting the cap taking into account the emissions baseline; (2) distributing allowances effectively; and (3) ensuring compliance.

One advantage of a load-side program is avoiding emissions "leakage." If leakage occurs, regional emissions may increase, compromising the effectiveness of the program in terms of emissions, and putting in-region sources at a competitive disadvantage. Using a load-based approach can eliminate the leakage problem because generators are not the point where emissions are regulated.

B. Carbon Intensity Measures

Unlike cap-and-trade programs, which call for absolute reductions in emissions of CO_2, carbon intensity measures call for reductions in emissions of CO_2 relative to an output measure, such as the gross domestic product (GDP) of a country. To reduce emissions intensity therefore means to reduce the amount of CO_2 emitted in producing each unit of GDP. This approach is appealing to countries whose economies are in significant growth phases, and for whom an absolute limit (such as a carbon emissions cap) could hinder the country's efforts to raise the standard of living to levels consistent with industrial economies. Furthermore, this approach is favored by many countries that believe historic emissions contribution levels to (i.e., responsibility for) the current climate change threat must be considered.

Current Status and Efforts

While not subject to binding emissions reductions requirements under international climate agreements, China and India both made voluntary commitments to reductions in carbon intensity in December 2009 at the 15th Conference of the Parties in Copenhagen, Denmark. In Copenhagen, China committed to reducing its emissions intensity by 40 to 45 percent of 2005 levels by 2020. This reduction goal covers CO_2 emissions from the consumption of fossil fuels and from industrial activity, but it does not cover emissions from land use and forestry. To help achieve its reduction goals, China's *Twelfth Five Year Plan* lays out various policy goals: a 16-percent energy intensity reduction target, a 17-percent carbon intensity reduction target, a target to increase non-fossil-fuel energy sources to 11.4 percent of primary energy consumption by 2015, and a cap on total energy use of four billion tons of coal equivalent annually.[94]

Days before the conference in Copenhagen, India announced that it would reduce its carbon intensity by 20 to 25 percent from 2005 levels by 2020. This target does not include emissions from agriculture. Analysis of the impact of various measures to lower emissions led to the specific intensity reduction target. Those measures have been detailed under either India's *National Action Plan on Climate Change* or under existing regulatory policies. Policies include: a planned amendment to the Energy Conservation Code, new fuel efficiency standards that take effect in 2011, deployment of supercritical and cleaner technologies in coal-fired power plants, increased forest cover to sequester 10 percent of annual emissions, increasing the fraction of electricity from wind, solar, and small hydro to 20 percent, from the current 8 percent, by 2020, and adoption of new green building codes by 2012.[95]

Numerous other countries with economies in development have adopted carbon and energy intensity reduction targets (see table in Appendix B – Summary of Carbon Intensity Targets and Goals).

Lessons Learned, Gaps in Knowledge, and Policy Directions

Emissions intensity targets provide a mechanism to decouple a country's GDP growth from its CO_2 emissions in a policy setting. This is especially important in countries like China and India, which have argued that their economies should be allowed to develop in the same way as the industrialized countries. Achievement of emissions intensity reduction targets can mean achieving greater efficiency in heavy industrial processes that require more energy and emit more carbon, making changes in the structure of an economy and the movement away from GHG-intensive industries, enacting policies to control emissions, or some combination of the three.[96]

94 Switchboard, 2011

95 India Climate Portal, 2009

96 Kolstad, 2003

China has successfully slowed the growth of its emissions through efforts made between 2006 and 2010, setting an energy intensity reduction target of 20-percent reduction compared to 2005 levels by 2010, replacing 54 GW of inefficient coal plants with more efficient facilities, closing outdated heavy manufacturing capacity, improving the efficiency of its top 1,000 energy-consuming facilities, and expanding its renewable resources to the extent that ten percent of the country's energy was produced by renewables by 2010.[97] Still, if China were to do no more than continue the policies already in place, although emissions intensity would be reduced by approximately 37 percent from 2005 levels by 2020, the country would still fall short of its 40- to 45-percent goal for 2020.[98] China therefore must make additional progress on the goals and policies described in the *Twelfth Five Year Plan* in order to meet its emissions intensity reduction targets.

Although India has established specific policies to help meet its Copenhagen goals, much uncertainty still surrounds its commitments. There is some question as to whether India's emissions intensity reduction target will lead the country to deviate very far from its "business as usual" GHG emissions path, especially because the country's commitments are voluntary and non-binding. "Domestically, there is expected to be much more debate on what carbon intensity cuts will imply, particularly for the manufacturing sector in India. Questions will also be raised as to whether India should adopt a softer 'energy intensity' metric, rather than a 'carbon intensity' one."[99]

India and China are not the only countries exploring voluntary emissions reduction targets. Several developed countries have established targets designed to reduce emissions from a "business as usual" trajectory. These commitments—called Nationally Appropriate Mitigation Actions (NAMAs)—are detailed in country letters to the UNFCCC.[100]

C. Resource Planning

Many countries around the world have programs that encourage or mandate the development of renewable resources and programs that are aimed at improving the end-use efficiency of customers. There are relatively few cases outside the United States, however, where the analysis used to develop a preferred set of options involves an integrated comparison of supply and demand options and their externalities, as in an Integrated Resource Plan (IRP).

There are some, however. Several areas (Malaysia, and British Columbia in Canada) are attempting to evaluate the total cost of alternatives, including externalities, of various supply and demand options, but it is unclear if the planning process is actually taking place. Other places like South Africa are undertaking an integrated evaluation of utility costs (without externalities) of various supply options, coupled with some mandated provisions for energy efficiency included in the plans. The commitment to energy efficiency and renewables is often generated outside of the planning exercise, as is done in Brazil, China, India, and Thailand, or takes the form of an obligation to demonstrate savings, as in many European countries. For these reasons, the following IRP section focuses on experience in the various US states.

Electric utilities in the United States have been practicing IRP since the late 1980s. The federal government defined IRP in the 1992 Energy Policy Act as a planning and selection process for new resources, evaluating a full range of alternatives that includes: new generating capacity, power purchases, energy conservation and efficiency, cogeneration and district heating and cooling applications, and renewable energy resources. Plans should provide for adequate and reliable service to electric customers at the lowest possible cost, taking into account system reliability, dispatchability, diversity, and other risk factors.[101]

Simply put, resource plans were the means by which utility planners, regulators, and the public could examine energy demand and use, resource selection, and risk in a comprehensive way and develop long-term plans to address these elements in an integrated manner. When the electric industry began to restructure in the mid-1990s, however, providing for retail competition in some jurisdictions and wholesale competition nationwide, IRP rules were repealed or suspended in some jurisdictions. In some cases these rules were replaced with least-cost procurement planning requirements, and have much in common with the old

97 Cohen-Tanugi, 2010

98 Cohen-Tanugi, 2010

99 India Climate Portal, 2009

100 See UNFCCC, Copenhagen Accord

101 Energy Policy Act of 1992

IRP rules. IRP processes have seen some rebirth in many jurisdictions, as well, since the mid-2000s. A number of resource planning rules require that the public be given the opportunity to review and comment on utility plans, and these plans are also reviewed by state utility commissions. Utility commissions may accept or reject all, or portions of, utility plans, and may also identify concerns with any aspect of the plan. Integrated resource or least-cost procurement planning is becoming more important as a policy strategy as states update planning rules to ask utilities to examine increasing amounts of renewable resources as part of their generation portfolios, consider advanced coal technologies, and evaluate the effects of emissions regulations and environmental externalities.

Current Status and Efforts

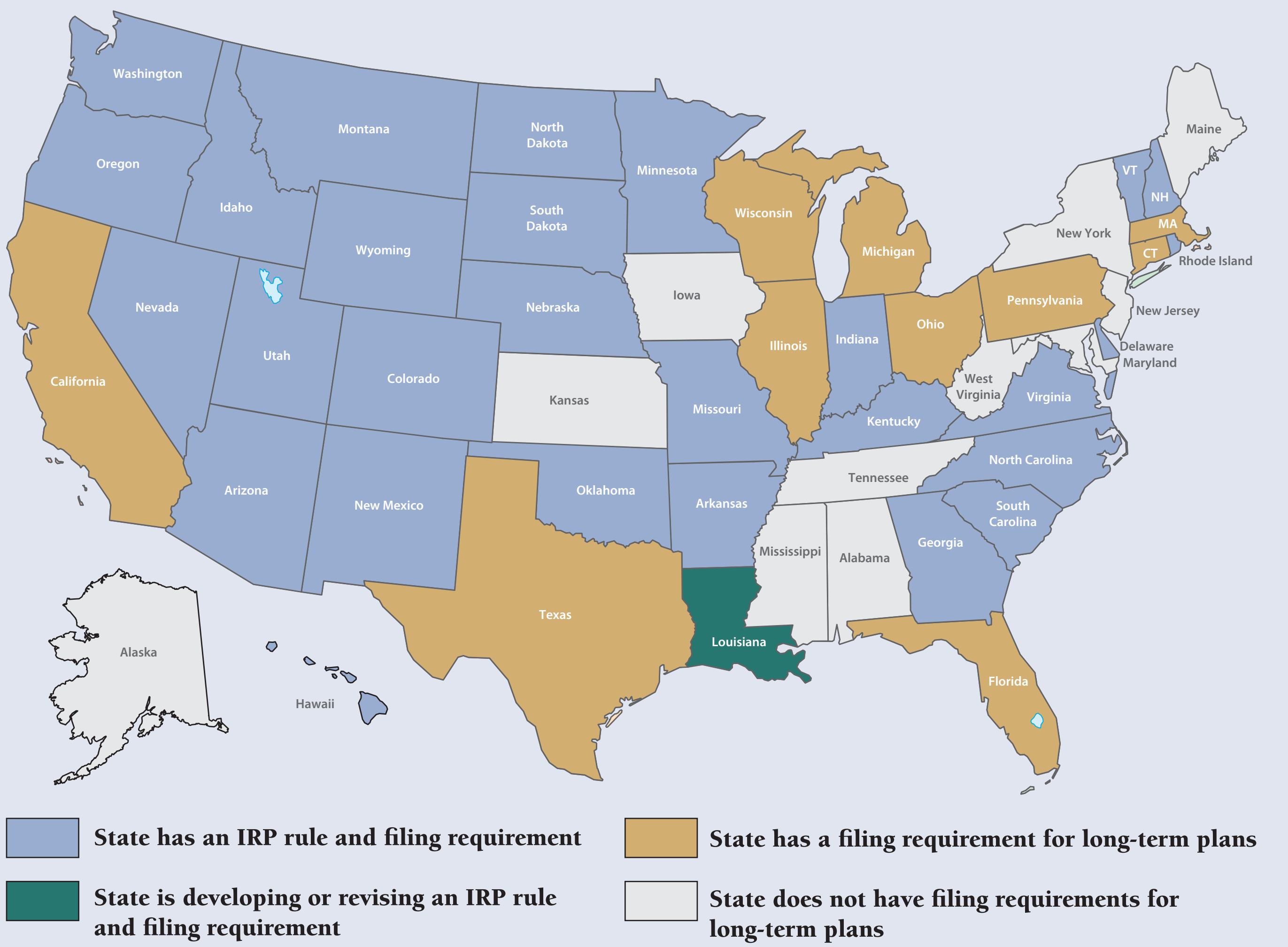
Thirty-nine of the 50 US states have a requirement for integrated resource or long-term procurement planning. States with requirements are shown in Figure 3.

Many IRP regulations leave the responsibility for the development and analysis of resource plans to the individual utility; however, there are ways in which the regulations can and do encourage decarbonization. Resource planning rules can promote decarbonization by

102 Wilson & Peterson, 2011. For another assessment of IRP status in the United States, see The Regulatory Assistance Project, 2009

Figure 3

Presence or Absence of State Integrated Resource Planning Rules and Procurement Plan Filing Requirements[102]



requiring utilities to examine the addition of renewable resources, greater end-user energy efficiency, and the adoption of more efficient fossil-fueled technologies. Arizona's rules, for example, state that utilities should consider a wide range of resources to promote fuel and technology diversity within resource portfolios.[103] In California, utilities must first reduce electricity demand through energy efficiency and demand-response, and then meet new generation needs with renewable and distributed generation resources. Remaining generation needs should be met with clean fossil-fueled generation.[104] Finally, the rules in Colorado state that "it is a policy of the state of Colorado that the Commission gives the fullest possible consideration to the cost-effective implementation of new clean energy and energy-efficient technologies."[105] Colorado utilities are required to provide at least three alternate plans in IRPs, one of which represents a baseline case and complies with renewable energy and demand-side management requirements. The alternate plans are to provide alternative combinations of resources that meet energy demand, but consist of proportionately more renewable resources, demand-side management resources, or "Section 123" resources. "Section 123" resources are new energy technology or demonstration projects, including new clean energy or energy-efficient technologies.[106]

Resource planning requirements can also promote decarbonization by asking utilities to evaluate the environmental externalities associated with electric power generation and/or the effects of a CO_2 adder on resource choices.[107] Most state resource planning rules are silent on the subject of externalities, and requirements are different in each of the states that do address externalities in their planning documents. In Hawaii, utilities may be asked to consider the impact of their power-generating resources on the environment. Other states ask utilities to quantify environmental externalities, including air emissions and water consumption. Finally, utilities may have to apply cost adders to reflect various environmental externalities. One such cost adder is the value associated with CO_2 emissions. There are nine states that specify the value of the carbon adder that should be considered by electric utilities in their resource plans: California, Colorado, Massachusetts, Minnesota, New Mexico, New York, Oregon, Vermont, and Wisconsin.

Lessons Learned, Gaps in Knowledge, and Policy Directions

One example of a successful application of resource planning as a policy instrument to achieve decarbonization occurred in Oregon. Portland General Electric (PGE) released its 2009 IRP in mid-2008 and held a series of stakeholder meetings before submitting the plan to the Oregon Public Utilities Commission (PUC). The PGE IRP called for the retrofit of its coal-fired Boardman coal plant to comply with air emissions regulations, and for the continued operation of the plant until 2040. Conservation groups in Oregon launched a campaign calling for the early shutdown of the Boardman plant. The PUC asked PGE to examine early retirement scenarios, which the company did, but still chose to move forward with the Boardman retrofit until a lawsuit from environmental groups spurred PGE to plan a 2020 closure for the plant. Ultimately the resource planning rules provided the foundation for closure of the plant by allowing stakeholder dialogue on the utility resource plan, asking for the consideration of replacement generating resources, and requiring the use of a carbon adder to reflect emissions costs in the analysis of continued operation of the Boardman plant. This analysis, which determined the externality cost to the environment of plant operations, led to the closure decision.[108]

Best practices in integrated resource or least-cost procurement planning include providing transparency, allowing for stakeholder participation, specifying consideration of low-carbon resource additions, evaluating environmental externalities, and including a carbon adder. As seen in Figure 1, some states do not require utilities to conduct resource planning. Of those states that do participate in resource planning, not all allow for stakeholder participation, and even fewer mandate valuation of environmental externalities or the use of a carbon adder. Resource plans are required to be updated periodically to reflect changing conditions related to the

103 Arizona Corporation Commission

104 California Assembly Bill 57, 2002

105 Colorado Department of Regulatory Agencies, 2010, p. 6.

106 Colorado Department of Regulatory Agencies, 2010, p. 7.

107 Wilson et al, 2012

108 Oregon Public Utility Commission, 2010

provision of electricity, so the rules governing resource planning should be changed to reflect best practices. Such changes are particularly appropriate now that the US Supreme Court determined in *Massachusetts vs. EPA* that the EPA is authorized to regulate CO_2 emissions.[109] The court's decision arguably modifies CO_2 emissions from an "externality" to a "risk," and most IRP processes require explicit consideration of risks and alternatives to them.

The EPA is coordinating the development and adoption of multiple regulations that will affect sources in the electric power sector. Such coordinated development of policies makes planning for compliance with multiple policies on an integrated basis particularly important in order to reach sound investment decisions for a fleet of power plants. The application of such an integrated planning process is closely related to integrated resource planning, but not identical. It is discussed further in Section E, concerning Impacts of Environmental Regulation.

D. Portfolio and Contract Emissions Standards

Performance standards establish a minimum threshold of performance according to some metrics related to emissions. There are different categories of performance standards, distinguished by their application on the supply side to emissions sources or contracts for power, or on the load side to load served by a particular entity. An Emissions Performance Standard (EPS) generally applies to generation sources and mandates an output-based emissions limit in pounds of CO_2 emissions per MWh produced. The standard can be applied to new generation, existing generation, or both. Most proposed and actual emissions performance standards apply to individual electric generation plants; however, such a standard can also be applied to a generating company's portfolio of resources, where the portfolio can be generating units owned at a specific site or generating units owned across a state. The generation sources bear the compliance obligation. Because it uses an average output-based standard, this mechanism could be adapted to incorporate demand-side resources along with supply-side resources to help achieve compliance. Closely related is a Procurement Emission Rate, an emissions standard applied to a long-term contract such that a regulated entity is prohibited from signing long-term contracts for power that exceed a certain emissions standard.

A Performance-Based Clean Energy Portfolio Standard applies to the entities that deliver electricity to end-users (Load Serving Entities, or LSEs), and mandates that their entire supply portfolio meet a certain output-based emissions limit (e.g., pounds of CO_2/MWh).[110] Unlike the EPS described above, LSEs rather than generators bear the compliance obligation. An LSE must thus ensure that the average emissions rate of all of the supply- and demand-side resources used to meet its customers' energy demand does not exceed the emissions limit. Compliance could be demonstrated through some combination of (1) supply contracts from specific resources, (2) average emissions associated with system power purchases, (3) trading carbon certificates, and (4) trading carbon offsets.

Current Status and Efforts

The US states of California, Oregon, and Washington each have an output-based standard for CO_2 emissions from new power plants of 1,100 lb of CO_2/MWh.[111] Earlier, the state of Massachusetts established an output-based standard of 1,800 lb of CO_2/MWh as part of its multipollutant regulations for existing power plants in the state; however, that standard was superseded by the state's participation in the RGGI.[112]

In California and Oregon these standards are part of more comprehensive standards that prohibit regulated entities (in this case investor-owned utilities) from building plants or signing contracts of greater than five years with resources whose emissions exceed 1,100 lb/MWh.[113]

Canada will apply an even more stringent performance standard on new plants, requiring them to achieve roughly the same GHG emissions rates as natural gas generators. As a result, new coal plants will likely require carbon capture technology, because coal typically releases twice as much

109 Massachusetts vs. EPA, 2007

110 Note, a performance-based standard could be used without specifying carbon, for example instead focusing on other pollutants such as SO_2 and/or NOx.

111 Center for Climate and Energy Solutions

112 The emissions limit was contained in CMR 7.29. For a discussion of output-based standards, see Section 4.E, Impact of Environmental Regulations.

113 Platts Electric Utility Week, 2011

CO_2 as natural gas does in the burning process. The rules require new coal units to emit no more than 375 tonnes CO_2/GWh of produced electricity, an emissions rate that is not yet achievable with current technology. These rules, however, apply only to new plants commissioned after July 2015.[114]

In the United States, Montana and Illinois also constrain utilities' ability to procure energy from new coal-fired power plants. Montana requires applications for new plant construction to include 50-percent carbon sequestration, and Illinois establishes a preference for coal-fired plants that use CCS.[115]

In the United Kingdom, government policy makers are also considering an EPS, presented in "Planning our electric future: a White Paper for secure, affordable and low-carbon electricity," (sic) which the government issued in July 2011. The White Paper sets out key measures to attract investment, reduce the impact on consumers' bills, and create a secure mix of electricity sources, including new nuclear, renewables, and CCS. One of the key measures set out in the White Paper is an EPS to provide a regulatory backstop on the amount of emissions new fossil fuel power stations can emit. Policy makers are currently considering details related to grandfathering, applicability to upgrades and life extensions, and exemptions for plants in the CCS demonstration program.[116]

China has been pursuing a policy of shutting down old, polluting, coal-fired plants. In its initial phase, this program focused on power plants with a capacity less than 50 MW, but in its most recent five-year plan the Chinese government decided to expand the policy. The Chinese Ministry of Environmental Protection plans to focus on generating units that have been operating for more than 20 years and whose capacity is less than 100 MW, generating units of less than 200 MW whose anticipated performance period has expired, and certain coal units whose coal consumption exceeds provincial or national averages.[117] China is also advanced in consideration of "Efficiency Power Plants" (EPP). An EPP is a set of energy efficiency programs configured so as to produce savings whose load profile looks like the output of a conventional power plant. Although in many countries energy efficiency has been developed as an alternative to supply, the emphasis on mirroring the output of a central power plant renders the substitutability more starkly apparent and can even make it easier to finance the energy efficiency programs on a per-kWh-saved basis.

Australia has included emissions thresholds in the development of some of its policies; for example, in the original version of the Clean Energy Future Plan, coal-fired generators with emissions intensity greater than 1.2 tonne CO_2-e per MWh of electricity on an "as generated' basis could apply for inclusion in a government-funded program to encourage the early retirement of approximately 2,000 MW of brown-coal generator capacity. In early September 2012, however, the Australian Government announced that it has not been able to reach agreement with the owners of any of the emissions-intensive power stations on a price for buying out and shutting down a power station. Consequently the buy-out program will not proceed. However, all power stations with emissions intensity above 1.0 tonne CO_2-e per MWh may be eligible for transition mechanisms to help moderate the financial impact of a carbon tax.[118]

E. Impacts of Environmental Regulation

The electric power sector is a significant source of multiple pollutants, including CO_2, SOx, and NOx, which contribute to the formation of ground level ozone, fine particulate matter, and acid rain—hazardous air pollutants, heavy metals, water contamination, and more. Environmental regulations that focus on emissions of pollutants other than GHGs can have a significant effect on GHG emissions from the power sector. When the effect is to reduce carbon emissions it is often called a "co-benefit" of environmental regulatory efforts focused on pollutants other than GHGs, and vice versa. The effect is most pronounced when environmental regulation adopts a multipollutant approach, such that a variety of

114 Climatewire, 2011

115 Simpson, Haushauer, & Rao, 2010

116 Information available at http://www.decc.gov.uk/en/content/cms/consultations/eps/eps.aspx

117 Information on China's Plan is available from Center for Climate and Energy Solutions at http://www.pewclimate.org/international/factsheet/energy-climate-goals-china-twelfth-five-year-plan

118 Crossley, 2012

environmental impacts are addressed in a single regulation or package of regulations. Output-based emissions standards—which encourage generation efficiency due to their focus on emissions per unit of output, in contrast to heat-rate-based emissions limits—are one example of a policy that results in reductions of criteria and toxic pollutants as well as carbon emissions.

Current Status and Efforts

The United States provides one example of the advantages of a multipollutant approach to environmental regulation. In the United States, the historic focus of federal environmental regulations has been on individual pollutants, has targeted specific media (air, water, land), and for the most part has not resulted in noticeable impact on CO_2 emissions.[119] Programs that are pollutant-specific can have a significant effect on CO_2 emissions—positive or negative. For example, the EPA recently proposed hazardous air pollutant regulations that contain significant limitations on various hazardous pollutants emitted by coal plants, including mercury, acid gases, chlorine, and metals. Fossil generators complying with the rule may find that it is more economical to retire than to invest in pollution control for compliance. On the other hand, many technologies for controlling criteria air pollutant and toxic air pollutants require power to operate, or reduce the efficiency of electric generation. These "parasitic loads" can therefore require additional fuel combustion to generate the same plant output, creating additional CO_2 emissions.

A multipollutant approach is likely to play a larger role in reducing GHG emissions and spurring a transition to a cleaner generation mix than single-pollutant regulations. For example, the EPA is pursuing ongoing coordinated efforts to develop a multipollutant approach to reducing emissions from new and existing fossil fuel resources.[120] As a consequence, a multipollutant perspective regarding investment decisions in the electric sector in the United States is warranted, and even facilitated by the EPA's approach. Such a multipollutant perspective can provide some certainty in investment decisions and can facilitate well-founded decisions on the economics of continued operation of a power plant compared with the option of retiring the plant.

In January 2010, the EPA announced its intention to ensure better air quality, promote a cleaner and more efficient power sector, and have strong but achievable reduction goals for SO_2, NOx, mercury, and other air toxics. Indeed, Administrator Lisa Jackson has emphasized the agency's efforts to take a multipollutant, sector-based approach to regulation in order to provide certainty and clarity.[121] Some of these regulations have a significant impact on existing coal-fired power plants due to their relatively higher emissions of criteria pollutants and GHGs. Environmental rules that are part of the coordinated approach include the following:

- Cross State Air Pollution Rule – formerly the Clean Air Transport Rule (Clean Air Act): would reduce SO_2 and NOx emissions by approximately 73 and 54 percent, respectively, from 2005 power plant emission levels in affected states. This rule was vacated in 2012.[122]
- The power plant mercury and air toxics standards (Clean Air Act): would reduce mercury from coal plants by 90 percent, and acid gas emissions from power plants by 90 percent.
- Coal combustion waste (also called "coal combustion residuals," or CCR) (Resource Conservation and Recovery Act): would reduce the risk of failure from surface impoundments and prevent the release of a broad range of metals and other contaminants to the environment.
- Cooling water intake structure and water effluent (Clean Water Act): would reduce harms to aquatic life due to being sucked into cooling systems, and reduce toxic-weighted pollutant discharge in water.
- GHGs (tailoring to focus on large sources and New Source Review, New Source Performance Standards) (Clean Air Act): would require new and existing sources to obtain permits outlining how they will control emissions using Best Available Control Technology (BACT).
- Revisions of the National Ambient Air Quality Standards (NAAQS) for SO_2, ozone, PM 2.5 (Clean Air Act): the EPA is reviewing its NAAQS for multiple pollutants.

119 Biewald & Johnston, 2009

120 Napolitano et al, 2009

121 See, e.g., Jackson, 2010

122 Colburn et al, 2012

The EPA's coordinated approach to regulations is designed to enable generation owners to make well-informed decisions regarding the cost-effectiveness of investing in compliance technology at existing generating units. There is no question that for some existing coal-fired units, retirement or repowering with natural gas will be the most economic option. The regulations are thus a potential catalyst for modifying the future resource mix in the power sector as existing resources become uneconomical.

There are many publicly available projections of coal capacity at risk under various regulatory policies; projections range from below 20 GW of coal retired in response to a single regulation, up to 120 GW of coal retired under a comprehensive set of regulations including air, water, waste, and GHG regulations. The prospect of transition in the electric sector has sparked discussions about potential impacts on electric system reliability, with some electric companies and public officials suggesting that the transition is too quick and reliability will be jeopardized, and other companies, public officials, and electric sector analysts believing that the power system has sufficient resources, market rules, and regulatory provisions to remain resilient and to manage this transition.[123]

As a result of the EPA's multipollutant approach, certain states and electric generating companies have undertaken comprehensive evaluations of their generation fleet to determine an optimal approach to meeting energy needs while achieving environmental and energy security objectives. One policy strategy that has been proposed is "Integrated Environmental Compliance Planning" (IECP), in which environmental regulatory requirements and their impact on existing generation would be considered along with potential costs of compliance options in a comprehensive, transparent process.[124] This would provide a holistic approach to reviewing a company's power plant fleet and thorough consideration of the costs of potential compliance alternatives. Responding to EPA requirements piecemeal is likely to result in inefficient and unnecessarily expensive decisions. The sheer number and wide coverage of the pending rules require that utilities and regulatory commissions consider their potential impact in a comprehensive, rather than singular, case-by-case basis, for reliability planning and cost-recovery purposes. IECP would provide a system-wide perspective that regulatory commissions need to inform future approval determinations, while avoiding the time-consuming process of reviewing all the statewide issues from scratch in each case.

In another example, Colorado has undertaken comprehensive planning in the form of a legislative mandate for utility "emission reduction plans" under House Bill (HB) 10-1365. The Colorado PUC describes that legislation as follows:

> *At the highest level, HB 10-1365 reflects the General Assembly's belief that Colorado will realize significant economic and public health benefits by addressing emissions from front-range coal-fired power plants in a coordinated fashion. Having made this determination that a comprehensive emission reduction strategy is in the public interest, the legislature tasked the Commission and other state agencies with vetting and shaping the plans proposed by regulated electric utilities.*[125]

The modified plan eventually ordered by the Colorado PUC included the retirement of five coal units in 2011 to 2017, conversion of two coal units to gas in 2014 and 2017 (although Public Service Colorado was also ordered to further study retirement options in its next IRP), and installation of controls on three units in 2014 to 2016. The coordinated development of regulations is also spurring other states such as Kentucky, Oklahoma, and Missouri to take a comprehensive look at the impact of the regulations on the coal-fired power plant fleet and consider how to best address these issues in upcoming proceedings on resource planning and investment decisions.

In China, environmental regulators are developing a similar multipollutant approach with the Ministry of Environmental Protection's regional air quality management rule (RAQM).[126] The RAQM focuses on nine key regions and anticipates the development of plans to achieve shared energy and air-quality management goals. The Ministry of Environmental Protection has announced on its website that emissions allowances for SO_2, NOx, and soot for thermal power plants would be reduced, and mercury

123 See, e.g., Bipartisan Center Staff, 2011

124 Sierra Club, 2011

125 Colorado Public Service Commission, 2010

126 James & Schultz, 2011

discharges from coal burning and emissions from gas-fired boilers would also be restricted for the first time. Beijing will also toughen emissions levels in environmentally sensitive regions.[127]

For many years environmental regulators have recognized that output-based regulatory approaches—emissions standards or emissions-allowance allocations on the basis of electrical output instead of fuel input—reward generation efficiency. The EPA states that:

> *Output-based environmental regulations (OBR) can be an important tool for promoting an array of innovative energy technologies that can help achieve national environmental and energy goals by reducing fuel use. OBR encourage energy efficiency and clean energy supply, such as CHP, by relating emissions to the productive output of the energy-consuming process. The goal of OBR is to encourage the use of fuel conversion efficiency as an air pollution control measure. Although OBR have been used for years in regulating some industrial processes, they have only recently begun to be applied to electricity and steam generation.*[128]

The EPA explains that:

> *most environmental regulations for power generators and boilers have established emissions limits based on heat input or exhaust concentration: that is, they measure emissions in pounds per million British thermal units (lb/MMBtu) of heat input or in parts per million (ppm) of pollutants in the exhaust stream. These traditional input-based limits do not account for the pollution prevention benefits of process efficiency in ways that encourage reduced energy use.*[129]

Energy-efficient generation technologies offer the combined benefits of reducing fossil fuel use, reducing emissions of multiple pollutants simultaneously, reducing multimedia environmental impacts (air, water, soil), spurring technology innovation, and reducing compliance costs.[130]

Lessons Learned, Gaps in Knowledge, and Policy Directions

Environmental regulation provides important opportunities to contribute to decarbonizing the electric sector. This section focuses on regulation of pollutants other than GHGs. There are multiple avenues for achieving co-benefits through regulation of a variety of environmental impacts from power generation—reductions in CO_2 emissions due to efforts focused on reducing other pollutants such as NOx, SO_2, air toxics, and water pollution. There is a need for some caution due to the potential for increased emissions associated with parasitic loads when pollution-control technologies require electricity and/or reduce the efficiency of power plants. Coordinated regulations that foster multipollutant consideration and facilitate investment decisions, however, can play a significant role in spurring a transition in the electric sector away from aging and pollutant-intensive power sources. A coordinated multipollutant approach can provide greater regulatory certainty than a pollutant-by-pollutant regulatory approach, and can facilitate comprehensive planning and more informed investment decision-making.

A multipollutant approach can be even more effective when developed as part of a "climate-friendly planning framework," in which policy measures that improve local air quality and reduce toxic and GHG emissions are combined, collaboration occurs between energy and environmental regulators, and upstream leverage points for emissions reductions (such as through efficiency improvements) are tapped.[131] This is a fruitful area for further policy exploration and development as the links between energy and environmental policy become increasingly evident and the crosscutting issues increasingly challenging.

127 China to tighten emissions from thermal power plants, 2011

128 US EPA, 2011. Also http://www.epa.gov/chp/state-policy/output.html

129 Idem.

130 Johnston, 2002. The Massachusetts Department of Environmental Protection (MA DEP) stated that output-based allocation of allowance provides several environmental benefits "including significant collateral reductions in emissions of other pollutants." In addition, the MA DEP stated: "The economic signal from an updated, output-based allocation, all else held equal, encourages the operation of generating facilities with lower rates of emissions of several other pollutants with significant public health and environmental benefits."

131 James & Schultz, 2011

Experience in the United States demonstrates that it is important that such coordinated regulation be developed in tandem with rules and procedures in the operation of the bulk power system, which ensure that the system can remain resilient even as existing aging power sources are retired and new, lower-carbon resources are brought online. Further, it is essential that economic regulatory commission proceedings, such as resource planning and investment review, also adopt and support the responsibility and opportunity for comprehensive consideration of the impact of multiple environmental regulations. It will be important to continue to improve the coordination between proceedings that look at individual investment decisions (e.g., whether to retrofit or retire a plant), compliance obligations associated with a specific regulation, overall power plant fleet planning, and implementation of government economic and environmental policy goals at all administrative levels.[132]

132 For more information, see Binz, Sedano, Furey, & Mullen, 2012; Farnsworth, 2011; and Farnsworth & Lazar, 2011

5. Policy Strategies Encouraging Low-Carbon Sources

One of the significant factors in decarbonizing the power sector is the availability of low carbon sources of power. Fortunately the past decade has been one of tremendous growth in the renewable generation sector; renewables supplied 16 percent of global final energy consumption in 2010. For the first time, investments in renewables surpassed investments in fossil fuel technology.[133] And there are very positive trends in the industry, with rapid growth of installed resources, ever-increasing numbers of countries adopting policies to support renewables, developing countries playing an increasingly important role in advancing renewable energy, and expanding geographic diversity in markets and manufacturing.[134]

There are numerous public policy mechanisms that focus specifically on ensuring that low carbon resources are available to meet demand for energy services as traditional high-carbon-emitting fossil fuel-fired power sources are phased out. As discussed previously, one effective policy approach for effecting a transition from carbon-intensive resources to low carbon resources is to combine a carbon price (in the form of a cap-and-trade program) with dedicating the cap-and-trade revenue to fund other clean energy policies. Another option—an overarching policy approach that can overlay a combination of strategies—is to incorporate, even mandate, a policy preference for low carbon sources in all decisions related to the power system. "Clean First" is a policy approach based on the idea that meeting climate and environmental policy goals should be part of the mandate for power sector regulators, even those whose role has traditionally been strictly economic regulation. It is a combination of policies based on the fact that energy and environment are linked. This policy's goal is to ensure that clean resources have preference over others in a variety of decision forums, such as siting new transmission, access to the transmission system, cost allocation, or grid operations.[135] Implementation of such an overarching approach likely requires a legislative mandate, as individual government agencies and decision-makers often are bound by mandates and limits on their authorities. Existing regulatory authority of economic or environmental regulators is usually narrower than would be necessary to effect a comprehensive government policy.

As pressures mount for the retirement of existing high carbon emissions power sources, governments should be poised to implement policies ensuring that any new resources that replace retired capacity are consistent with long-term environmental and energy policy goals. The IPCC finds that under most conditions, increasing the share of renewable energy in the resource mix will require policies to stimulate changes in the energy system.[136] A number of such policy options are described below.

A. Reducing Emissions from Coal

One of the most important policies to help spur the development of CCS is a price on power plant emissions of CO_2, whether in the form of a carbon tax or an allowance price under a cap-and-trade program. Stable and clear carbon policies are a key ingredient to encouraging investment in CCS. Companies in the United States were beginning the development of CCS projects immediately before and after the Waxman-Markey climate bill was passed by the House of Representatives in 2009, but several of those projects were shelved when no law was enacted that put a price on CO_2 emissions.

Another policy strategy is an outright prohibition on new coal without CCS. The United Kingdom implemented a policy in April 2009 that allows for no new coal plants unless the CO_2 emissions can be captured and sequestered. A new coal plant would be forced to demonstrate CCS

133 See Bloomberg, 2012

134 REN21, 201; also, IPCC. *Special Report on Renewable Energy Sources and Climate Change.* (2011, May).

135 Regulatory Assistance Project, 2010

136 IPCC, 2011

at the beginning of its operations, trapping the emissions equivalent of 300 MW. After CCS technology is proven to be commercially viable—which is expected to occur by 2020—plants would have five years to install CCS on 100 percent of their output.[137] This approach is also discussed above in the section on emissions standards.

A significant number of the new coal plants under construction around the world are located in developing countries that lack the funds to install CCS technologies. Several countries have advocated for the inclusion of CCS in the UNFCCC's Clean Development Mechanism (CDM), and decision text was adopted in late 2010 at the Conference of the Parties (COP) in Cancun, Mexico, that "legitimizes the merit of CCS as a mitigation option within the context of the UNFCCC objectives, as well as its capacity to be able to systematically generate tradable credits under the CDM."[138] Inclusion of CCS in the CDM may help move capital toward these projects, encouraging greater investment in CCS projects in the developing world by both developing and developed countries.[139]

Similar to agreements between countries that are designed to aid in the development of advanced coal technologies, bilateral agreements between countries can also be helpful to promote CCS technologies. An MOU was signed by China and the United States on July 28, 2009, in which the two countries agreed to collaborate on cleaner use of coal and the development of CCS.[140]

B. Encouraging Non-Fossil Resources

Renewable Portfolio Standards (Obligations, Quotas)

Some government entities have specified that a minimum proportion of a utility's resource mix must be derived from renewable resources. These policies are called renewable portfolio standards (RPS), renewables obligations, or renewables quotas.[141] These policies require electric utilities and other retail electric providers to supply a specified minimum amount—usually a percentage of total load served—with electricity from eligible resources. The standards range from modest to ambitious, and qualifying energy sources vary by jurisdiction (country, province, or state). Closely related to this approach is a Clean Energy Standard (CES), which is much like an RPS but includes supply resources that are deemed to be "clean" even if not renewable (e.g., nuclear energy).

In general, the goal of an RPS policy is to increase the development of renewable resources by creating a market demand that makes them more economically competitive with other forms of electric generation that are less costly but produce more pollution. There are multiple other policy objectives that drive this policy approach; they can include climate change mitigation, job creation, energy security, and cleaner air.

There are numerous issues to consider in developing an RPS. These include the definition of "renewable"; which resources qualify; the appropriate target level; defining the base quantity of electricity sales upon which a company's portfolio standard for renewables is set; tracking of renewable energy credits or attributes; regional differences; differing credit for certain resources; banking, trading and borrowing of credits; alternative compliance options; and coordination with other policies.

Several countries in the European Union have renewables obligations, and many US states have adopted RPS or alternative energy portfolio obligations (AEP). In the United States, the first RPS was established in 1983, but a majority of states passed or strengthened their standards after 2000. Consequently, while many of these efforts have increased the penetration of renewables, others have not been in effect long enough to do so. Many states allow utilities to comply with the RPS (or CES or AEP) through tradable credits, such as renewable energy credits (RECs) or alternative compliance payments (ACPs).

RPSs or quota policies have been enacted at the national level in ten countries and in at least 50 other jurisdictions, including 30 US states (plus Washington, DC) and the Canadian province of British Columbia. Countries with a renewable standard or quota include Australia, China, Italy, India, Japan, Korea, Poland, Romania, Sweden, and the United Kingdom.[142]

137 Carrington, 2009

138 Global CCS Institute, 2011

139 Global CCS Institute, 2011

140 Switchboard: Natural Resources Defense Counsel Blog, 2009

141 REN21, 2011

142 Chapter 11 of the IPCC Special Report on Renewable Energy summarizes and analyzes many of these renewable energy obligations. http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch11 Section 11.5.4.3, p. 31.

Coordinated Resource Procurement

A coordinated resource procurement approach, under which states would pursue contracts with individual distribution companies or state agencies for power, could also help to reduce GHG emissions. Vermont has had such a mechanism in place since the 1980s.[143]

This approach is also under consideration in the other New England states, as well as in western US states. According to a report on coordinated renewable procurement by the Northeast States Committee on Electricity (NESCOE), every New England state has statutory authority to approve long-term contracts for capacity, energy, and/or RECs.[144] The NESCOE report explores the possibility of coordinated regional procurement of renewables and determines that it is feasible and could offer significant benefits in increasing the development of renewables in New England.

In the United Kingdom, the electric companies that bear a renewable obligation have developed a coordinated procurement mechanism, the UK Non-Fossil Purchasing Agency (NFPA).[145] Of course, this is different from coordinated procurement by states, but can nevertheless provide a useful example of the strengths and pitfalls of implementing such an approach. The NFPA was created in 1990 by the 12 Regional Electric Companies in England and Wales to act as their agent for meeting their obligations to purchase electric generating capacity from renewable sources. Payments to generators who won the periodic solicitations were funded through a "fossil fuel levy," a tax on all electricity. Winning offers from specific technology categories were selected based on price, and received long-term contracts to supply electricity to the grid. The last three competitive bids resulted in contracts of 15 years with a five-year grace period for getting the project operational.[146] The NFPA purchases power under these long-term contracts and conducts auctions for renewable electricity, usually twice each year, in which electricity suppliers bid for the right to receive electricity from renewable projects.

C. Developing New Clean Energy Sources

In order to ensure that necessary resources will be available to effect a transition of the electric sector to a carbon constrained future, an effective approach will need to include a plan for promoting and coordinating further research and development of low- and zero-carbon resources. One significant issue pertains to investment in renewables research, development, and deployment.[147] Current levels of investment in research, development, and deployment of low- and zero-carbon resources appear insufficient to attain the emissions reductions trajectory necessary to avoid dangerous climate change impacts. According to the IPCC, "the higher values of the annual averages of the [renewable energy] power sector investment [those consistent with lower GHG stabilization concentrations] approximately correspond to a five-fold increase in the current global investments in this field."[148]

Clean Energy Deployment Administration Model

One approach to supporting development of clean energy programs is the use of a central financing authority such as the Clean Energy Deployment Administration (CEDA) model found in a number of recent US legislative proposals.[149] CEDA would be an independent administration within the DOE. Its purpose would be to provide various types of credit vehicles to support the deployment of clean energy technologies. These would include loans, loan guarantees, and other credit enhancements, as well as secondary market support to develop products such as clean energy-backed bonds that would enable less expensive financing from the private sector. CEDA could also accommodate riskier debt and thus provide a mechanism for piloting deployment of the most innovative technologies. The Australian Climate Change Plan also includes provisions for funding innovative technologies.

The IPCC has concluded that "Public R&D investments in RE technologies are most effective when complemented by other policy instruments, particularly deployment

143 Vermont Public Service Board Rule 4.100, available at http://www.state.vt.us/psb/rules/4100boun.htm.

144 NESCOE, 2011

145 Information on the NFPA is available at www.nfpa.co.uk

146 Information is available at http://www.repp.org/repp_pubs/articles/issuebr14/04Britan.htm

147 The topic of innovative financing for energy efficiency and clean energy resources is discussed in more detail in another paper in this series, paper #2.

148 IPCC, 2011

policies that simultaneously enhance demand for new technologies."[150] This conclusion is consistent with findings in other sections of this paper on the importance of a cohesive package of complementary policies and strategies that ensure availability of low carbon technologies and strategies for effecting a transition from the current high carbon electric power system to an innovative low carbon power system.

D. Electricity Market Issues

Nontraditional resources such as renewable energy and demand response (DR) can be integrated into electricity systems, but doing so requires overcoming technologic, institutional, and political challenges. System characteristics such as generation mix, resource flexibility, network infrastructure, energy market designs, institutional rules, concerns about reliability, and demand characteristics will all affect the integration of renewables into electricity systems. This section provides an overview of market modifications to facilitate the adoption of these nontraditional resources, such as DR.

There are a variety of solutions to the specific challenges that arise in renewable energy integration. For example, development of complementary flexible generation; improved short-term forecasting, system operation, and planning tools; availability of DR and electricity storage technologies; transmission and distribution infrastructure improvements; and modified market rules and procedures are all components in making existing electricity systems and markets more accessible to renewable energy sources. The IPCC finds that:

> *… there are few, if any, fundamental technological limits to integrating a portfolio of RE technologies to meet a major share of total energy demand in locations where suitable RE resources exist or can be supplied. However, the actual rate of integration and the resulting shares of RE will be influenced by factors such as costs, policies, environmental issues and social aspects.*[151]

In 2008, wind energy provided for nearly 20 percent of electricity consumption in Denmark, more than 11 percent in Portugal and Spain, 9 percent in Ireland, nearly 7 percent in Germany, more than 4 percent of all EU electricity, and nearly 2 percent in the United States. Efforts are already well underway in European nations and China to integrate wind supply into the bulk power system, and research continues.[152]

A number of market modifications could be made to help decarbonize the supply of electric power through the use of DR. Some have already been accomplished in electricity markets in the United States. Allowing DR to participate in regional capacity, energy, and ancillary services markets is one step; this has been successfully implemented in New England, New York, PJM (mid-Atlantic region), the Midwest, and California.[153] But DR is not well integrated into the day-ahead and real-time energy markets or the ancillary services markets anywhere (although PJM does allow DR to participate in one of its reserve markets). The Federal Energy Regulatory Commission's Order 745 on DR compensation in wholesale markets should help increase participation in the energy markets for DR, but the implementation of those changes is at least a year away.

There are opportunities to implement DR in a manner that helps integrate variable generation in the power system; however, additional research and policy initiatives are necessary.[154] Multiple minor changes to energy market rules (like exemption from penalties for erroneous production estimates) have helped wind to be able to participate in certain markets. A few regions allow flywheel storage to provide frequency regulation in wholesale markets. In some respects, the most important step is for system operators to gain experience with new technologies and to allow them time to figure out how to operate the system with wind, biomass, solar, and DR instead of just nuclear, natural gas, oil, and coal.

149 See, e.g., American Clean Energy Leadership Act 2009 (S. 1462), and the American Clean Energy and Security Act 2009 (HR. 2454).

150 IPCC, 2011

151 Idem.

152 IEA Wind, 2011. Integration of renewables into wholesale electricity markets is discussed in more detail in another paper in this series, paper #10.

153 Gottstein, 2011

154 Capers et al, 2011

6. Conclusion

The task of decarbonizing the electric sector is a daunting one; the electric sector is currently the largest source of global GHG emissions and trends indicate that electricity consumption will grow. Fortunately there is already good progress in developing technology and policy strategies to decarbonize the electric sector. Beyond honing design and implementation of individual strategies, one of the most important areas for exploration and innovation will be in changing the overarching decision frameworks to enable the extent of decarbonization in the electric sector that will be necessary to achieve scientifically based GHG reduction goals.

Efforts to develop strategies are truly global, and with most strategies being implemented in at least two geographic areas and with variations in design details, there is ongoing opportunity for learning and refining strategies. Promising technology strategies include efforts to reduce emissions from existing sources through increasing efficiency of electricity generation, developing CCS technologies, and developing non-fossil resources. Pursuing a combination of retiring the oldest and most polluting coal-fired facilities in combination with seeking opportunities to increase the efficiency of other facilities is a strategy that some countries (such as India, China, and Australia) are pursuing with promising results. Technologies that improve coal plant efficiency offer potential for near-term reductions in CO_2 emissions and are available commercially; however, low coal and natural gas prices are currently dampening economic signals for advanced coal technologies. Furthermore, there are limits to the amount of CO_2 reductions that efficiency technologies can achieve, so these technologies should be used to complement other emissions reduction strategies.

CCS is still in development for electric sector applications, and although some skeptics believe that the technology will ultimately prove infeasible, others believe it can play an important role in a portfolio of emissions reduction strategies. There are numerous pilot projects in implementation stages; however, technology and policy hurdles must be overcome before large commercial scale application of CCS can be used in the electric sector. Stable policy support combined with a carbon price signal would foster confidence and support investment in CCS necessary to drive down capital and operating costs. Non-fossil technologies, including renewable energy, fuel cells, distributed technologies, and possibly nuclear generation are promising components of a decarbonization strategy. Continued efforts in research, development, and deployment are key to the availability of these technologies on a scale sufficient to affect electric sector GHG emissions, as are continuing efforts to enable integration of nontraditional resources into operation of the existing electric system. Multiple policy strategies can also facilitate and encourage the transition to greater reliance on renewable energy sources.

Policy strategies discussed in this paper focus on multiple components of an effort to decarbonize the power sector through:

- increasing efficiency of fuel conversion (e.g., through output-based emissions standards, use of a carbon price, government mandate, and technology assistance among countries);
- altering the mix of fossil fuels (e.g., through performance standards, planning processes, plant retirement due to regulatory mandates or simple economics, and multipollutant emissions regulations);
- avoiding uncontrolled GHG emissions (e.g., prohibitions on uncontrolled emissions, performance standards, and CCS requirements); and
- reducing dependence on fossil fuels (e.g., use of a carbon price combined with complementary policies, resource planning, performance standards, multipollutant emissions regulations, and policies that spur non-fossil resources).

Many of these policies can be adapted for regional variations, and different policy strategies are suited to different country circumstances (e.g., developed or developing nations, integrated electric grid or dispersed resources, different forms of regulation, competitive markets or managed "markets," and so on). Implementation experience in different countries and geographic areas demonstrates that many policies have wide applicability and that specific variations can be pursued to suit particular situations.

One of the overarching conclusions from a wide-ranging review of decarbonization strategies is the importance of interactions among strategies. Technology strategies and policy strategies are each important vehicles for decarbonization, and optimal approaches will employ and coordinate them both. Indeed, coordination of strategies—both technologic and policy oriented—is essential to effective and economical decarbonization efforts. Although an individual strategy can achieve some decarbonization, it is most effective to develop a suite of strategies—technologic and policy focused—to achieve emissions reductions most economically.

Experience from implementation efforts in different countries is showing that there are certain synergies among strategies. For example, a carbon price is one important instrument for overcoming the omission of carbon emissions as a cost factor in markets; however, the price is less effective and economical on its own than as part of a package of complementary policies, as has been demonstrated in some of the early efforts to implement carbon-cap strategies and complementary policies (funded either with auction proceeds or otherwise). The European Union and the northeastern United States have been implementing carbon pricing coupled with complementary programs, and program evidence demonstrates the effectiveness of this combination. It is most economically effective if some of the revenue from a carbon pricing mechanism is channeled into strategies, such as energy efficiency, that contribute to electric sector decarbonization.

It is essential to adopt policies that will contribute to sustained financial support for a transition from the status quo to a less carbon-intensive sector (despite increasing electrification in light-duty transport and in developing countries). Most important, efforts to discourage the use of carbon-intensive resources and encourage alternatives are approaches that complement each other. Complementary policies reduce the cost of achieving emissions reduction goals under the cap and are able to spur emissions reductions from activities that are not covered and/or not sufficiently incentivized by an established carbon price mechanism.

Other synergies exist among strategies. For example, development of clear multipollutant environmental regulations is most effective in decarbonizing the electric sector when there is some comprehensive planning mechanism, such as IRP or government agency planning, that facilitates evaluation of and comparison among resource options. Multipollutant strategies are being implemented in the United States and China and are often coupled with planning processes (IRP in the United States and more central planning in China). To reduce GHG emissions embedded in the electric sector, it is critical to encourage resource turnover in the power sector. Investing in long-lived resources with high emissions, or extending the life of existing high-emissions resources beyond their planned lifetimes, are decisions that essentially lock in continued high emissions. To steer away from that continued commitment to high emissions, it can be useful to use some combination of emissions-intensity goals, performance standards, and targeted plant closings. Portions or all of Canada, Australia, the United States, China, and other countries are developing performance standards. China, India, and Australia are using combinations that include intensity goals, performance standards, and targeted plant closings to ensure turnover in the electric sector. This approach pushes transformation of the power sector and facilitates transition to an electric sector viable in a carbon-constrained world.

Progress in developing and implementing technology and policy strategies is heartening. However, a wholesale transformation of the electric sector requires a corresponding transformation in the overall context within which resource decisions are made. Changing the resource base of the electric sector to a degree sufficient to meet climate change challenges requires more than technology and policy strategies within existing decision paradigms. It requires new decision frameworks, including changes in decision processes, infrastructure design and operation, and economic incentives.

Modifying decision frameworks to adapt to the reality of providing electricity services in a carbon-constrained world is one of the most important areas for innovation and future strategy development. Overcoming institutional inertia and jurisdictional constraints of existing regulatory environments presents a significant challenge; however, it is possible, and already underway in many places. In the United States, for example, the EPA's coordinated approach to regulating power sector pollutant impacts illustrates change in progress. Affected facilities, regional power systems, economic regulators, and environmental regulators are making adjustments in their decision-making mechanisms, policies, and procedures that will ultimately result in a cleaner, more carefully planned and resilient power system. In China, government agencies are exploring mechanisms for meeting environmental and economic policy goals in a coordinated fashion.

Climate change and decarbonizing the power sector demand a comprehensive approach that goes way beyond the sum of authorities and capabilities that exist in the power sector today in most countries. The combination of government authorities, use of market forces, power system infrastructure, and power system operation methods that is characteristic of a particular country requires that each country find a balance of tools for achieving GHG reduction goals. Beyond the technology and policy strategies, other promising areas for exploration include:

- Clean First policies ensuring that selection of clean resources is a primary consideration in multiple decision forums. Major focuses for making this approach effective include aligning regulatory agencies' authorities with public policy goals, and determining how to ally power system design and operation with public policy goals.

- The role of resource and power system planning. There is a solid base of information on IRP based on implementation experience in a regulated utility context. New applications are being explored to suit new contexts that combine utility regulation with market mechanisms. One emerging challenge is in planning for and harmonizing achievement of competing objectives (such as electric system reliability and security, avoiding dangerous climate change, and reasonable electricity costs) on a state, province, regional, or national scale. The entities that have the capability and authority for comprehensive power system planning and operation are in many countries not the same as the entities charged with implementing public policy, and do not bear the same responsibilities. Furthermore, aligning market forces with public policy objectives is a complex and difficult undertaking. Developing planning tools and procedures that permit informed public policy development, while enabling the use of market forces, will require sophistication and coordination among the wide range of electric power system participants.

- Climate-friendly air quality management that incorporates tools to improve local air quality as well as mechanisms for reducing GHG emissions. Collaboration among energy and environmental regulators to achieve economic and public health benefits is emerging as a fruitful area, not only to ensure that economic and environmental regulation do not operate at cross purposes, but also to enhance efficiency in achieving public policy objectives. Further development of this concept, coupled with details of implementing the approach in specific federal or sub-federal jurisdictions, is likely to improve resource management and enhance electric sector decarbonization.

Ultimately this review of decarbonization strategies demonstrates the wealth of information and opportunity that arises from learning by doing—and the potential for learning from the study of other implementation efforts. All of the strategies described herein are part of what can be considered a decarbonization laboratory. This paper provides an overview and identification of practices being implemented in countries throughout the world. More detailed study of individual strategies can inform the development of a decarbonized electric sector. The most successful strategy will include sustained support through clean energy strategies, as well as sustained discouragement of emissions-intensive fossil generation.

Appendix A – Recommended Reading

The following information sources, presented in alphabetical order, are recommended for those interested in additional reading materials on decarbonizing the electric sector. Please see the Bibliography for additional resources.

California Air Resources Board. *Updated Economic Analysis of California's Climate Change Scoping Plan*—Staff Report to the Air Resources Board; CARB. March 2010.
Analysis of a combination of complementary policies designed to achieve an emissions reduction goal. Analysis results provide insight into the dynamics of policy interactions. Available at: http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/updated_sp_analysis.pdf

Center for Climate and Energy Solutions (formerly Pew Center on Climate Change) provides numerous policy summaries for countries throughout the world. It is an excellent resource for overviews and summaries of scientific issues, technology issues, and policy issues. http://www.pewclimate.org/

Cowart, Richard. *Prices and Policies: Carbon Caps and Efficiency Programmes for Europe's Low-Carbon Future.* Presented at the 2011 ECEEE Summer Study. June 2011.
Discussion of complementary policies in the European context. Available at: http://www.raponline.org/document/download/id/931.

European Climate Foundation. *Roadmap 2050*. April 2010.
Presents a practical plan for effecting a transition to a low-carbon European economy; includes discussion of decarbonizing the electric sector, energy efficiency, modifications to the European ETS, electricity grid integration, and energy market reform among other topics. Available at: http://www.roadmap2050.eu/

India Climate Portal. A useful website portal for information specific to climate change in India, including links to policy briefs and to the Indian Parliament's activities on climate change. http://www.indiaclimateportal.org/

International Energy Agency. *Climate and Electricity Annual 2011—Data and Analyses;* OECD/IEA Paris, France; 2011.
Provides statistics related to CO_2 emissions and the electric sector across ten regions of the world. Also provides topical analyses about topics related to curbing CO_2 emissions from both electricity policy and technology perspectives. Available for purchase at: http://www.iea.org/w/bookshop/add.aspx?id=410

Hibbard, Tierney, Okie, Darling. *The Economic Impacts of the Regional Greenhouse Gas Initiative on Ten Northeast and Mid-Atlantic States,* Analysis Group; November 2011.
The most comprehensive analysis of RGGI's economic impact based on data from the first three years of operation. Analysis illustrates the importance of complementary programs in enhancing economic benefits from a cap-and-trade program. It focuses on the actual impacts of economic activity: known CO_2 allowance prices; observable CO_2 auction results; dollars distributed to the RGGI states; actual state government decisions about how to spend the allowance proceeds; measurable reductions in energy use from energy efficiency programs funded by RGGI dollars; traceable impacts of such expenditures on prices within the power sector; and concrete value added to the economy. Available at: http://www.analysisgroup.com/uploadedFiles/Publishing/Articles/Economic_Impact_RGGI_Report.pdf

James and Schultz. *Climate-Friendly Air Quality Management, Strategies for Co-Control.* Regulatory Assistance Project, November 2011. Available at: http://www.raponline.org/document/download/id/4700

Review and analysis of the mechanisms for and benefits of coordination among economic and environmental regulators in achieving public policy goals.

Metz, Davidson, Bosch, Dave, & Meyer (Eds.). *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

The IPCC's report from the working group on climate change mitigation. It provides a comprehensive, worldwide overview of scientific knowledge related to the mitigation of climate change. It includes a detailed assessment of costs and potentials of mitigation technologies and practices, implementation barriers, and policy options for the sectors: energy supply, transport, buildings, industry, agriculture, forestry, and waste management. The IPCC will issue its next Assessment Report in 2013/2014.

Productivity Commission 2011. *Carbon Emission Policies in Key Economies.* Research Report. Canberra.

Comprehensive survey of a variety of policies in several different countries combined with development of a method of figuring out the implicit carbon cost of those policies. Good overview of GHG emissions reduction strategies in the electric sector as well as other sectors. Available at: http://www.pc.gov.au/projects/study/carbon-prices/report

REN21. Renewables 2011: *Global Status Report.* REN21 Secretariat, Paris, France. 2011. Also IPCC. *Special Report on Renewable Energy Sources and Climate Change; May* 2011.

These two resources provide a thorough overview, and specific summaries, of renewable energy technologies and policies. They are useful resources for those new to renewables as well as to those with a more substantial background in renewables issues. Available at: http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf. Available at: http://srren.ipcc-wg3.de/report.

Appendix B – Bibliography

Al-Juaied & Whitmore. (2009, July). *Realistic Costs of Carbon Capture*. Harvard Kennedy School Discussion Paper 2009-08.

Alberta Environment. (2007, July 18). *Specified Gas Emitters Regulation*. Technical Guidance Document for Baseline Emissions Intensity Applications. Retrieved from http://environment.gov.ab.ca/info/library/7811.pdf

Andersen, M.S. (2010). Europe's Experience with Carbon-Energy Taxation. *Sapiens*, 3(2). Retrieved from http://sapiens.revues.org/1072

Arizona Corporation Commission Decision No. 71722, in Docket No. RE-00000A-09-0249. Amends Arizona Administrative Code Title 14, Chapter 2, Article 7, "Resource Planning." Retrieved from http://images.edocket.azcc.gov/docketpdf/0000112475.pdf

Australia senate passes carbon tax. (2011, November 8). *Greenwire*.

Australia's Carbon Tax: Breaching the Brick Wall. (2011, July 11). *The Economist*. Retrieved from http://www.economist.com/blogs/banyan/2011/07/australias-carbon-tax

Australia's Clean Energy Future Plan. (2011, July). Retrieved from http://www.cleanenergyfuture.gov.au/clean-energy-future/our-plan/

Australia's lower house passes carbon tax. (2011, October 12). *Greenwire*.

Balboa (2009). *$3-B tidal power plant proposed near Korean islands*. EcoSeed. Retrieved from http://www.ecoseed.org/water-power-blog/wave-and-tidal-energy/article/64-wave-and-tidal-energy/3457-$-3-b-tidal-power-plant-proposed-near-korean-islands

Bhaskar, U. (2010, March 2). Japan to help India with modernizing power plants. *The Wall Street Journal*. Retrieved from http://www.livemint.com/2010/03/02214849/Japan-to-help-India-with-moder.html

Beer, J. (2009). *Higher efficiency power generation reduces emissions*. National Coal Council Issue Paper, 2-3. Retrieved from http://web.mit.edu/mitei/docs/reports/beer-emissions.pdf

Bianco, N., & Litz, F. (2010, July). *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action*. Washington, DC: World Resources Institute. Retrieved from http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action

Biewald & Johnston. (2009, April 1). *Co-Benefits Experience and Lessons from the U.S. Electric Sector*. Published in Pollution Atmosphérique Retrieved from http://www.synapse-energy.com/Downloads/SynapsePaper.2009-04.0.Co-Benefits-Pollution-Atmospherique.A0024.pdf

Bipartisan Center Staff. (2011, June). *Environmental Regulation and Electric System Reliability*. Bipartisan Policy Center. Retrieved from http://www.bipartisanpolicy.org/sites/default/files/Executive%20Summary%20-%20Electric%20System%20Reliability_0.pdf

Binz, R., Sedano, R., Furey, D., & Mullen, D. (2012, April). *Practicing Risk Awareness: What Every State Regulator Needs to Know*. The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/4909

Blakenship, S. (2008). The evolution of carbon capture technology part 1. *Power Engineering*. Retrieved from http://www.power-eng.com/articles/print/volume-112/issue-3/features/the-evolution-of-carbon-capture-technology-part-1.html

Bloomberg New Energy Finance. (2010, January 14). *Carbon Markets – North America – A fresh look at the costs of reducing US carbon emissions.* Retrieved from http://bnef.com/Download/UserFiles_File_WhitePapers/NEF_RN_Carbon_Markets_NAmerica_2010_01_USMACC.pdf

Bloomberg (2011, November 25). *Renewable Power Trumps Fossils for First Time as UN Talks Stall.* Retrieved from: http://www.bloomberg.com/news/2011-11-25/fossil-fuels-beaten-by-renewables-for-first-time-as-climate-talks-founder.html

California Air Resources Board. (2008, December). *Climate Change Scoping Plan.* Retrieved from http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf

California Air Resources Board. (2010, March). *Updated Economic Analysis of California's Climate Change Scoping Plan – Staff Report to the Air Resources Board.* Retrieved from http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/updated_sp_analysis.pdf

California Assembly Bill 57. (2002).

California Public Utilities Commission. (2010, November 9). *Greenhouse Gas Emissions Performance Standard.* Retrieved from http://www.cpuc.ca.gov/PUC/energy/Climate+Change/070411_ghgeph.htm

Capers et al. (2011, October). *Mass Market Demand Response and Variable Generation Integration Issues: A Scoping Study.* Lawrence Berkeley Laboratory. Retrieved from http://eetd.lbl.gov/ea/emp/reports/lbnl-5063e.pdf

Carbon Tax Center. http://www.carbontax.org/

Carrington, D. (2009, April 23). No new coal without carbon capture, UK government rules. The Guardian. Available at http://www.guardian.co.uk/environment/2009/apr/23/carbon-capture-plans

Center for Climate and Energy Solutions, *Emissions Caps for Electricity.* Retrieved from http://www.pewclimate.org/what_s_being_done/in_the_states/cap_and_offset_map.cfm

Chang, White, Johnston & Biewald. (2010, October). *Electricity Energy Efficiency Benefits of RGGI Proceeds: An Initial Analysis.* Synapse-Energy Economics. Retrieved from http://www.synapse-energy.com/Downloads/SynapseReport.2010-10.RAP.EE-Benefits-of-RGGI-Proceeds.10-027.pdf

Chen, K. (2011, September 1). China government think tank outlines national ETS proposal. *Point Carbon.* Retrieved from http://www.pointcarbon.com/news/1.1575155

China Aims to Unify Carbon Trading Platform by 2015, News Says. (2011, June 27). *Bloomberg News.* Retrieved from http://www.bloomberg.com/news/2011-06-27/china-aims-to-unify-carbon-trading-platform-by-2015-news-says.html

China to Extend Oil, Gas Resource Tax Nationwide Next Month. (2011, October 11). *Bloomberg News.* Retrieved from http://www.bloomberg.com/news/2011-10-10/china-resource-tax-for-crude-oil-gas-set-at-5-10-of-sales.html

China to Tighten Emissions from Thermal Power Plants. (2011, September 22). *Reuters* Beijing. Retrieved from http://uk.reuters.com/article/2011/09/22/us-china-emission-power-idUKTRE78L0U120110922

Climatewire. (2011, August 22). *Canada moves to phase out coal.*

Cohen-Tanugi, D. (2010, October). *Putting it into Perspective: China's Carbon Intensity Target.* NRDC White Paper. Retrieved from http://china.nrdc.org/files/china_nrdc_org/Chinas%20Carbon%20Intensity%20Target%20in%20Perspective.pdf

Colburn, Farnsworth, Shenot, Kadoch, Watson & Wigg. (November, 2012). *Least-Risk Planning.* Public Utilities Fortnightly. http://www.raponline.org/document/download/id/6245

Colorado Department of Regulatory Agencies. Public Utilities Commission. 4 Code of Colorado Regulations (CCR) 723-3, Part 3: Rules Regulating Electric Utilities. Decision No. C10-1111.Docket No. 10R-214E. Filed November 22, 2010. Retrieved from https://www.dora.state.co.us/pls/efi/EFI.Show_Docket?p_session_id=&p_docket_id=10R-214E

Colorado Public Service Commission. (2010, December 9). Final Order in Docket No. 10M-245E, ¶2.

Congressional Research Service. (2010, February 22). Costa Rica: Background and US Relations. Retrieved from http://assets.opencrs.com/rpts/R40593_20100222.pdf

Cowart, R. (2009, October). *Carbon Caps and Efficiency Resources: Investing Carbon Dioxide Revenues to Lower Costs and Accelerate GHG Progress*. Retrieved from http://www.raponline.org/document/download/id/679

Cowart, R. (2009, March 19). *Carbon Caps and the Power Sector: Global Goals, Essential State Roles*. London: Institution of Mechanical Engineers. Retrieved from http://www.raponline.org/document/download/id/33

Cowart, R. (2010, July). *Climate Caps and Complementary Policies: Europe's Clean Energy Policies are Central to ETS Success*. Retrieved from http://www.raponline.org/document/download/id/688

Cowart, R. (2011, June). *Prices and Policies: Carbon Caps and Efficiency Programmes for Europe's Low-Carbon Future*. Presented at the 2011 ECEEE Summer Study. Retrieved from http://www.raponline.org/document/download/id/931

Cowart, R., & Farnsworth, D. (2009, April 28). *Meeting the Climate Challenge: Policy Options for the Power Sector.* Colorado PUC Workshop on Climate Change and Utility Regulation. Retrieved from http://www.raponline.org/document/download/id/681

Crossley, D. (2012, September). *Australian Clean Energy Future Plan*. The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/6115

Daowoo E., & C. *Sihwa Tidal Power Plant Project*. Retrieved from http://pemsea.org/eascongress/international-conference/presentation_t4-1_kim.pdf

Database of State Incentives for Renewables & Efficiency. Retrieved from http://www.dsireusa.org/

de Figueiredo, M. (2005). *Property interests and liability of geologic carbon dioxide storage*. Retrieved from http://sequestration.mit.edu/pdf/deFigueiredo_Property_Interests.pdf

DB Advisors. (2008, October). *Investing in Climate Change 2009 – Necessity and Opportunity in Turbulent Times.* Deutsche Bank.

EcoSecurities Consulting Limited. (2009, January 30). *Forecasting the Future Value of Carbon – A Literature Review of Mid- to Long-Term Carbon Price Forecasts*. Report for the NWPCC.

Eisenhauer, J., & Scheer, R. (2009, July 15 16). *Opportunities to improve the efficiency of existing coal-fired power plants*. United States National Energy Technology Laboratory. Retrieved from http://www.netl.doe.gov/energy analyses/pubs/NETL%20Power%20Plant%20Efficiency%20Workshop%20Report%20Final.pdf

Electric Power Research Institute. (2011, June). *Program on Technology Innovation: Integrated Generation Technology Options*, p. 4-1.

Ellerman & Joskow. (2008, May). *The European Union's Emissions Trading System in Perspective*. The Pew Center on Global Climate Change. Retrieved from http://www.pewclimate.org/docUploads/EU-ETS-In-Perspective-Report.pdf

Elmendorf, D. (2009, October 14). *The Economic Effects of Legislation to Reduce Greenhouse-Gas Emissions* – Statement before the Committee on Energy and Natural Resources, United States Senate. Washington, DC: Congressional Budget Office.

Emissions are Under-Priced in Europe. (2011, September 13). Bloomberg New Energy Finance Press Release.

Emissions trading system significant to green growth. (2001, December 13). *China Daily USA.*

Energy Policy Act of 1992. §111(d)(19). Retrieved from http://www.ferc.gov/legal/maj-ord-reg/epa.pdf

Environment Northeast. (2011, May). *RGGI Emissions Trends*. Retrieved from http://www.env-ne.org/public/resources/pdf/ENE_RGGI_Emissions_Report_110502_FINAL.pdf

European Climate Foundation. (2010, April). *Roadmap 2050*. Retrieved from http://www.roadmap2050.eu/

European Commission. (2011, March). *Investment needs for future adaptation measures in EU nuclear power plants and other electricity generation technologies due to effects of climate change.* Retrieved from http://ec.europa.eu/energy/nuclear/studies/doc/2011_03_eur24769-en.pdf

ExxonMobil. (2009, December). *Outlook for Energy – A View to 2030.* Retrieved from http://www.exxonmobil.com/corporate/files/news_pub_eo_2009.pdf

Farnsworth, D. (2011, July). *Preparing for EPA Regulations: Working to Ensure Reliable and Affordable Environmental Compliance.* The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/919

Farnsworth, D., & Lazar, J. (2011, October). *Incorporating Environmental Costs in Electric Rates: Working to Ensure Affordable Compliance with Public Health and Environmental Regulations.* The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/4670

Fawcett, A. A., et al. (2009, October 28). *Overview of EMF 22 U.S. Transition Scenarios.* Elsevier B. V. 2009. Retrieved from http://emf.stanford.edu/files/res/2369/fawcettOverview22.pdf

Finnish Ministry of the Environment. (2011, April 14). *Environmentally related energy taxation in Finland.* Retrieved from http://www.environment.fi/default.asp?contentid=147208

Finnish National Board of Customs. (2011, January). *Customer Bulletin No. 21.* Retrieved from http://www.tulli.fi/en/finnish_customs/publications/excise_tax/excise_taxation/021.pdf

Fisher, J., Jackson, S., & Biewald, B. (2012, January 24). *DRAFT: The carbon footprint of electricity from biomass.* Prepared for the Regulatory Assistance Project, Montpelier VT.

Folger, P. (2009, June 19). *Carbon Capture and Sequestration.* Washington, DC: Congressional Research Service Report for Congress, RL33801.

France May Earn 200 Million Euros From Planned Carbon Tax. (2011, September 28). Bloomberg New Energy Finance Carbon Markets / TOP STORIES / France

Gallagher, J. T. (2011, October 11). NY Wholesale Electricity Markets & the Effect of RGGI on Imports. Presentation to RGGI Inc.

Gallucci, M. (2011, April 14). Financial shortfall at America's first CCS plant highlights absence of carbon price. *Reuters.* Retrieved from http://www.reuters.com/article/2011/04/14/idUS375884024020110414

Global CCS Institute. (2011). *The Global Status of CCS: 2011.* Retrieved from http://cdn.globalccsinstitute.com/sites/default/files/the_global_status_ccs_2011.pdf

Global Climate: India Says Australian Carbon Tax a 'Useful Idea.' (2011, September 13). *The Conversation.* Retrieved from http://theconversation.edu.au/global-climate-india-says-australian-carbon-tax-a-useful-idea-3356

Gottstein, M. (2011, May 3). *Advancing Both European Market Integration and Power Sector Decarbonisation: Key Issues to Consider.* Retrieved from http://www.raponline.org/document/download/id/879

Gottstein, M. (2011, July). *Capacity Markets for a Decarbonised Power Sector: Challenges and Lessons.* Presentation to the Ministry for Environment, Climate and Energy of Baden-Wurttemberg. Retrieved from http://www.raponline.org/document/download/id/4430

Gottstein, M. (2011, August 9). *Examples for Dispatchable Demand Response Clearing the ISO-New England and PJM Forward Capacity Markets.* Montpelier VT: The Regulatory Assistance Project.

Goubet & Delbosc. (2011, May). *Design of multi-sector Emissions Trading Systems: a comparison of European and American experiences.* CDC Climate Research. Retrieved from http://www.cdcclimat.com/Climate-Report-no28-Design-of.html?lang=en

Government of India. (2008, July). *National Action Plan on Climate Change.* New Delhi: Prime Minister's Council on Climate Change. Retrieved from http://pmindia.nic.in/Pg01-52.pdf

Government of Australia. (2011). *Securing a Clean Energy Future: The Australian Government's Climate Change Plan.* Retrieved from http://www.cleanenergyfuture.gov.au/wp-content/uploads/2011/07/Consolidated-Final.pdf

Hibbard, Tierney, Okie, & Darling. (2011, November). *The Economic Impacts of the Regional Greenhouse Gas Initiative on Ten Northeast and Mid-Atlantic States.* Analysis Group. Retrieved from http://www.analysisgroup.com/uploadedFiles/Publishing/Articles/Economic_Impact_RGGI_Report.pdf. Holly, C. (2011, December 12). Deal reached to launch new talks on binding climate pact. The Energy Daily. Retrieved from http://www.ccap.org/

Hornby, Warfield, & Mazlowski. (2007, December 13). *Role of Long-Term Power Purchase Agreements in Fostering Development of Wind Energy Projects in New England.* Report to the Union of Concerned Scientists.

India Climate Portal. (2009, December). Policy Brief. *India announces energy intensity target.* Retrieved from http://www.indiaclimateportal.org/component/option,com_policybrief/view,policybriefdetail/id,20

IEA Wind. (2011, July). *2010 Annual Report.* ISBN 0-9786383-5-2. Retrieved from http://www.ieawind.org/IndexPagePOSTINGS/IEA%20Wind%202010%20AR_cover.pdf

International Energy Agency. *Addressing Climate Change, Policies and Measures, CO_2 Tax, Norway.* Retrieved September 6, 2011, from http://www.iea.org/textbase/pm/?mode=cc&id=3548&action=detail.

International Energy Agency. http://www.iea.org/subjectqueries/cdcs.asp

International Energy Agency. (2011). *Climate and Electricity Annual 2011 – Data and Analyses.* Paris, France: OECD/IEA. Retrieved from http://www.iea.org/w/bookshop/add.aspx?id=410

International Energy Agency. (2009). *Cleaner coal in China.* p. 248. Retrieved from http://www.iea.org/textbase/nppdf/free/2009/coal_china2009.pdf

International Energy Agency. (2010). *World Energy Outlook 2010.* pp. 275-6.

International Energy Agency. (2011). *CO_2 emissions from fuel combustion: highlights.* Retrieved from http://www.iea.org/co2highlights/co2highlights.pdf

International Energy Agency. *Global renewable energy, policies and measures, implementation of the law on the reduction of CO_2 emissions.* Retrieved from http://www.iea.org/textbase/pm/?mode=red&action=detail&id=514

International Energy Agency. *Energy Technology Perspectives 2010.* Retrieved from http://www.iea.org/techno/etp/index.asp

International Energy Agency. (2009). *Technology roadmap: Carbon capture and storage.* p. 4.

International Energy Agency. (2011, November). *World Energy Outlook 2010.* Paris, France: OECD/IEA. Retrieved from http://www.iea.org/Textbase/npsum/weo2010sum.pdf

International Energy Agency/Carbon Sequestration Leadership Forum. (2010). *Carbon Capture and Storage – Progress and Next Steps; Report to the Muskoka 2010 G8 Summit.* Retrieved from http://iea.org/papers/2010/ccs_g8.pdf Article on this report states that C price in range of $80/ton is necessary to create incentive for CCS.

IPCC Fourth Assessment Report. (2007). In: *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.* Metz, Davidson, Bosch, Dave, Meyer (Eds). Cambridge, United Kingdom, and New York, NY, USA: Cambridge University Press. See Technical Summary and Chapter 4.4.

IPCC. (2011, May). *Special Report on Renewable Energy Sources and Climate Change.* Retrieved from http://srren.ipcc-wg3.de/report

Jackson, L. (2010, September 14). Remarks on the 40th Anniversary of the Clean Air Act, As Prepared. Retrieved on October 15, 2011, from http://yosemite.epa.gov/opa/admpress.nsf/8d49f7ad4bbcf4ef852573590040b7f6/7769a6b1f0a5bc9a8525779e005ade13!OpenDocument.

James, C. *Implementing Policies to Reduce Air Pollution, Improve Energy Security and Protect Climate: Where Models Lead, Will Leaders Follow?* (2010, September 14). Vancouver, BC: 15th World Clean Air Congress. Retrieved from http://www.raponline.org/document/download/id/192

James, C. (2011, April). *Market-based mechanisms for GHG reduction – overview of some key lessons from international experience.* Anhui, Yellow Mountain, China: International Symposium on China's Low Carbon Finance Policies and Mechanisms. Retrieved from http://www.raponline.org/document/download/id/654

James, C. (2011, March 26). *Regional Air Quality Management in the Context of Climate Change: Perspectives from the US.* Nanjing, China. Retrieved from http://www.raponline.org/document/download/id/653

James & Schultz. (2011, November). *Climate-Friendly Air Quality Management, Strategies for Co-Control.* Montpelier VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/4700

Jervey. (2011, January 21). China Gets Over a Quarter of its Electricity from Clean Energy Sources. *Good Magazine.* Retrieved from http://www.good.is/post/china-gets-over-a-quarter-of-its-electricity-from-clean-energy-sources/

Johansson, & Bengt. (2000). *Economic Instruments in Practice 1: Carbon Tax in Sweden.* Swedish Environmental Protection Agency. Retrieved from http://www.oecd.org/dataoecd/25/0/2108273.pdf

Johnston, Hausman, Biewald, Wilson, & White. (2011, February). *2011 Carbon Dioxide Price Forecast.* Synapse Energy Economics. Retrieved from http://www.synapse-energy.com/Downloads/SynapsePaper.2011-02.0.2011-Carbon-Paper.A0029.pdf

Johnston. (June 2002). *Multi-pollutant Approaches in Certain OTR States.* Synapse Energy Economics; prepared for the Ozone Transport Commission. Retrieved from http://www.synapse-energy.com/Downloads/SynapseReport.2002-06.OTC.Multi-Pollutant-Programs.01-73.pdf

Keith, G. (2010, May 11). *Beyond Business As Usual: Investigating a Future without Coal and Nuclear power in the U.S.* Synapse Energy Economics; prepared for the Civil Society Institute. Retrieved from http://www.synapse-energy.com/Downloads/SynapseReport.2010-05.CSI.Beyond-Business-as-Usual.10-002.pdf

Kolstad, C. (2003, August 18). *The Simple Analytics of Greenhouse Gas Emission Intensity Reduction Targets.* Santa Barbara: University of California. Retrieved from http://www2.bren.ucsb.edu/~kolstad/publications/pdf/SimpleAnalytics.pdf

Laitner, S. (2009, July). *The Positive Economics of Climate Change Policies: What the Historical Evidence Can Tell Us.* ACEEE.

Lazar. (2011, March). *Electricity Regulation in the US: A Guide.* The Regulatory Assistance Project. Retrieved from http://www.raponline.org/docs/RAP_Lazar_ElectricityRegulationInTheUS_Guide_2011_03.pdf

Lazard, Ltd. (2010, May). *Levelized Cost of Energy Analysis – Version 4.0.*

Lewis, J. (2011, March). *Energy and Climate Goals of China's 12th Five-Year Plan.* Pew Center on Global Climate Change. Retrieved from http://www.pewclimate.org/docUploads/energy-climate-goals-china-twelfth-five-year-plan.pdf

Massachusetts Department of Energy and Environmental Affairs. (2010, December 29). *Massachusetts Clean Energy and Climate Plan for 2020.* Retrieved from http://www.mass.gov/eea/docs/eea/energy/2020-clean-energy-plan.pdf

Massachusetts Institute of Technology. (2007). *The future of coal – Options for a carbon-constrained world.*

Massachusetts Institute of Technology. (2011). *Carbon capture and sequestration technologies database.* Retrieved from http://sequestration.mit.edu/tools/projects/index.html

Massachusetts vs. EPA, 549 US 497 (2007). Retrieved from http://www.law.cornell.edu/supct/html/05-1120.ZO.html

McKinsey & Company. (2009). *Pathways to a Low-Carbon Economy – Version 2 of the Global Greenhouse Gas Abatement Cost Curve.*

McKinsey & Company. (2008, September 22). *Carbon Capture & Storage: Assessing the Economics.*

Metz, Davidson, Bosch, Dave, & Meyer (Eds.) (2007). In: *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Ministry of Environment and Forests, Government of India. (2010, June 30). *India: Taking on Climate Change. Post-Copenhagen Domestic Actions*. Available at http://www.indiaenvironmentportal.org.in/files/India%20Taking%20on%20Climate%20Change.pdf

Ministry of Finance, British Columbia. (2008, February 19). Budget and Fiscal Plan 2008/09 - 2010/11. Available at http://www.bcbudget.gov.bc.ca/2008/bfp/2008_Budget_Fiscal_Plan.pdf

Ministry of Economy, Trade and Industry of Japan and the Planning Commission of India. (2010, May 7). *Joint Statement on the Occasion of the Fourth Meeting of the Japan-India Energy Dialogue*. Retrieved from http://www.enecho.meti.go.jp/policy/international-affairs/data/20100507en.pdf

Mohan, K. (2011, May 25-26). *Perform Achieve Trade (PAT) Mechanism in India*. Workshop on Market Mechanisms to Support China's Energy and Climate Goals. Beijing, China. Available at http://www.raponline.org/document/download/id/914

Napolitano et al. (2009, January). *A Multi-pollutant Strategy – An integrated approach could prove more effective for controlling emissions*. Public Utilities Fortnightly. Retrieved from http://www.epa.gov/airmarkt/resource/docs/multipstrategy.pdf

National Coal Council. (2011, March 18). *Expedited CCS development: Challenges & opportunities*. Retrieved from http://www.nationalcoalcouncil.org/reports/03_29_11_Final_NCC_Report.pdf

National Development and Reform Commission. (2011, March 5). *Report on the Implementation of the 2010 Plan for National Economic and Social Development and on the 2011 Draft Plan for National Economic and Social Development – Fourth Session of the Eleventh National People's Congress*.

National Renewable Energy Laboratory. (2009, December). *Carbon Taxes: A Review of Experience and Policy Design Considerations*. Retrieved from http://www.nrel.gov/docs/fy10osti/47312.pdf

National Energy Technology Laboratory. (2010). *Improving the efficiency of coal-fired power plants for near term greenhouse gas emissions reductions*. Retrieved from: http://www.netl.doe.gov/energy-analyses/pubs/ImpCFPPGHGRdctns_0410.pdf

Navigant Consulting, Inc. (2010, May). *Electricity Imports, Exports and Leakage in the Eastern WCI Partners: Quebec, Ontario and Manitoba*. Toronto, Canada; Prepared for Western Climate Initiative.

NESCOE. (2011, July). *Report to the New England Governors on Coordinated Resource Procurement*. Retrieved from http://www.nescoe.com/uploads/Report_to_the_Governors_July_2010.pdf

Netherlands Ministry of Housing, Spatial Planning and Environment. (2004). *The Netherlands' Tax on Energy: Questions and Answers*. Retrieved from http://www.wind-works.org/FeedLaws/Netherlands/NLEnergytax2004.pdf

New England States Committee on Electricity. (2010, July 12). *Report to the New England Governors on Coordinated Renewable Procurement – Identifying cost-effective, clean energy resources through competitive processes*. Retrieved from http://nescoe.com/uploads/Report_to_the_Governors_July_2010.pdf

New York Climate Action Council. (2010, November 9). *New York Climate Action Plan Interim Report*. NYSERDA. Retrieved from http://nyclimatechange.us/InterimReport.cfm

New Zealand Climate Change Information. *Emissions Trading Scheme*. Retrieved on December 13, 2011, from http://www.climatechange.govt.nz/emissions-trading-scheme/

Nuclear Energy Institute. Resources and Stats. *Costs: Fuel, Operation and Waste Disposal*. Retrieved on December 8, 2011, from http://www.nei.org/resourcesandstats/nuclear_statistics/costs/

OECD. (2011, September). *Environmental Taxation Guide for Policymakers*. Retrieved from http://www.oecd.org/dataoecd/17/7/48164926.pdf

Oregon Public Utility Commission. (2010, November 23). Portland General Electric 2009 Integrated Resource Plan, Order No. 10-457. Retrieved from http://apps.puc.state.or.us/orders/2010ords/10-457.pdf

Pew Center on Global Climate Change. (2008). *Tax Policies to Reduce Greenhouse Gas Emissions*. Pew Center Congressional Policy Brief.

Pew Center on Global Climate Change. (2010, March). Retrieved from Coal In China: Resources, Uses, and Advanced Coal Technologies.

Pew Center on Global Climate Change. (2011, January). *Climate Change 101: International Action*. Retrieved from http://www.pewclimate.org/docUploads/climate101-international.pdf

Pew Center on Global Climate Change. *Climate Change Mitigation Measures in the European Union*. Retrieved from http://www.pewclimate.org/brief/international/mitigation-measures-european-union

Pew Center on Global Climate Change. (2011, September). *Common Metrics: Comparing Countries' Climate Pledges*. Retrieved from http://www.pewclimate.org/docUploads/country-pledge-brief.pdf

Pew Center on Global Climate Change. (2009, June). Retrieved from A Performance Standards Approach to Reducing CO_2 Emissions from Electric Power Plants.

Pew Center on Global Climate Change. (2009, February). Retrieved from Positioning the Indian Coal-Power Sector for Carbon Mitigation: Key Policy Options

Pew Center on Global Climate Change. (2007, October). Retrieved from A Program to Accelerate the Deployment of CO_2 Capture and Storage: Rationale, Objectives, and Cost.

Pew Center on Global Climate Change. (2008, October). Retrieved from A Resource and Technology Assessment of Coal Utilization in India.

Pew Center on Global Climate Change. (2008, February). Retrieved from State Policy Options for Low-Carbon Coal Policy.

Pew Center on Global Climate Change. (2008, July). *Summary: India's National Action Plan on Climate Change*. Retrieved from http://www.pewclimate.org/international/country-policies/india-climate-plan-summary/06-2008

Pew Center on Global Climate Change. (2008, January). Retrieved from A Trust Fund Approach to Accelerating Deployment of CCS: Options and Considerations.

Platts Electric Utility Week. (2011, July 11).

Power Engineering. (2011). *Mountaineer CCS project deemed a success*. Retrieved from http://www.power-eng.com/articles/2011/05/mountaineer-ccs-project-deemed-a-success.html

Prime Minister's Council on Climate Change. (2008). National action plan on climate change. Government of India. Retrieved from http://pmindia.nic.in/Pg01-52.pdf

Productivity Commission. (2011). *Carbon Emission Policies in Key Economies*. Research Report, Canberra. Retrieved from http://www.pc.gov.au/projects/study/carbon-prices/report

Rastogi, N. P. (2011, June). Winds of Change: India's Emerging Climate Strategy. *The International Spectator*. Retrieved from http://www.iai.it/pdf/articles/rastogi.pdf

Regional Greenhouse Gas Initiative. Retrieved from www.rggi.org

Regulatory Assistance Project. (2008, February). *China's Power Sector: A Backgrounder for International Regulators and Policy Advisors*. Retrieved from www.raponline.org/document/download/id/13

Regulatory Assistance Project. (2009, December). *US States with Integrated Resource Planning or Similar Planning Process*. Retrieved from http://www.raponline.org/document/download/id/4447

Regulatory Assistance Project. (2010, September). *Clean First: Aligning Power Sector Regulation with Environmental and Climate Goals*. Retrieved from http://www.raponline.org/document/download/id/12

Regulatory Assistance Project. (2011, September). *Power Sector Policy in China: Next Steps*. Retrieved from http://www.raponline.org/document/download/id/4598

Regulatory Assistance Project. (2011, August). *US States with Integrated Resource Planning or Similar Planning Process (Effective December 2009)*. Retrieved from http://www.raponline.org/document/download/id/4447

REN21. (2011). *Renewables 2011: Global Status Report.* Paris, France: Secretariat. Retrieved from http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf

Roadmap 2050. Retrieved from http://www.roadmap2050.eu/

Rogner, Zhou, Bradley, Crabbe, Edenhofer, Hare (Australia), Kuijpers, Yamaguchi. (2007). Introduction. In: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Metz, Davidson, Bosch, Dave, Meyer (Eds.), Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Shirley, W. *Characteristics of Effective Resource Planning.* Presentation at Asia-Pacific Dialogue on Clean Energy Governance and Regulation; June 21-22, 2010. Regulatory Assistance Project. Retrieved from www.raponline.org/.../RAP_Shirley_CharacteristicsofEffectiveResourcePlanning_2010_06_21.pdf

Sierra Club. (2011, July 18). Response to Issues and Questions On Behalf of Sierra Club On the Topic of Fuel-Source-Related Issues. Submitted to the Oklahoma Corporation Commission in Cause No. PUD 201100077.

Simpson, Haushauer, & Rao. (2010). *Emissions Performance Standards in Selected States – Research Brief.* Montpelier VT: Regulatory Assistance Project.

Singh, H. (2011, October 11). *California Cap and Trade and Electricity Imports.* Presented at RGGI Learning Session, Retrieved from http://www.rggi.org/docs/ProgramReview/LearningSession1/Presentation_Harry_Singh_Goldman_Sachs.pdf

State/Federal RPS Collaborative. (2009, January). Recommended Principles and Best Practices for State Renewable Portfolio Standards. Retrieved from http://www.cleanenergystates.org/JointProjects/RPS/RPS_Principles_and_Best_Practices_Final_012609.pdf

Steinhurst, W. (2007). *Testimony Regarding Long-Term Procurement Plans.* Synapse Energy Economics. Prepared for the California Division of Ratepayer Advocates in proceedings regarding PG&E, SDG&E, and SCE.

Steinhurst, et al. (2006, October). *Energy Portfolio Management: Tools and Practices for Regulators.* Prepared by Synapse Energy Economics for the National Association of Regulatory Utility Commissioners.

Sun, G. (2010, March). *Coal in China: Resources, Uses, and Advanced Coal Technologies.* Pew Center on Global Climate Change. Retrieved from http://www.pewclimate.org/white-papers/coal-inititive/coal-china-resources-uses-technologies

Switchboard: Natural Resources Defense Council Staff Blog. (2011, March 5). *China Puts Forth Energy Intensity, Carbon Intensity and Total Energy Consumption Targets in Twelfth Five Year Plan in Effort to Tackle "Unsustainable Economic Growth."* Retrieved from http://switchboard.nrdc.org/blogs/bfinamore/china_puts_forth_energy_intens.html

Synapse Energy Economics. (2010, May 11). *Beyond Business As Usual: Investigating a Future without Coal and Nuclear Power in the U.S.* Prepared by Synapse Energy Economics for the Civil Society Institute.

Taylor, L. (2011, August 5). A decade before carbon tax influences electricity sector. *Sydney Morning Herald.* Retrieved on October 17, 2011, from http://www.smh.com.au/environment/climate-change/a-decade-before-carbon-tax-influences-electricity-sector-20110804-1idh6.html

The UK carbon floor price: How to enhance its credibility with investors. (2011, March 11). *Climate Change Capital.* Retrieved from http://www.climatechangecapital.com/news-and-events/press-releases/the-uk-carbon-floor-price-how-to-enhance-its-credibility-with-investors-ccc-thinktank-report.aspx

Thompson, J. (2011, September 14). *PM Introduces Carbon Price Legislation.* ABC News. Retrieved from http://www.abc.net.au/news/2011-09-13/pm-introduces-carbon-tax-legislation/2897250

Tierney, & Shatzki. (2008, July). *Retail Electricity Supply: Recent Trends in State Policies and Utility Practices*. National Association of Regulatory Utility Commissioners. Retrieved from http://www.naruc.org/resources.cfm?p=141

Torys, LLP. (2007, June 12). *Quebec government to implement carbon tax*. Torys Climate Change Bulletin. Retrieved from http://www.torys.com/Publications/Documents/Publication%20PDFs/CCB2007-6.pdf

Tracy, S. B. (2009, April 14). *Various State Approaches to Long-Term Agreements with Renewable Energy Generators for Energy, Capacity, and RECs*. Bernstein Shur Counselors at Law, presentation to the Maine Ocean Energy Task Force. Retrieved from http://www.maine.gov/spo/specialprojects/OETF/Documents/Apr14'09_TFmtg/tracy_longtermapproaches.pdf

Trexler, M. C. *Reviewing the Results of Carbon Market Forecasting*. Retrieved on October 19, 2010, from http://www.nwcouncil.org/energy/grac/NWPCC_EcoSecurities_Seminar_004.ppt

UK Department of Energy and Climate Change. (2010, July 27). *Annual Energy Statement- DECC Departmental Memorandum;* p. 18. Retrieved from http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/237-annual-energy-statement-2010.pdf

UK Department of Energy and Climate Change, HM Treasury. (2010, March). *UK Energy Market Assessment*. Retrieved from http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/d/budget2010_energymarket.pdf

UNFCCC, Copenhagen Accord. *Nationally appropriate mitigation actions of developing country Parties*. Retrieved from http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

United Nations Framework Convention on Climate Change. (2012). Kyoto Protocol. Retrieved on September 26, 2012, from http://unfccc.int/kyoto_protocol/items/2830.php

United States Agency for International Development and National Energy Technology Laboratories. (2010). *Clean energy research and deployment initiative assessment report on cleaner coal technology*. Retrieved from http://www.usaid.gov/in/working_with_us/pdfs/ann_2.pdf

US DOE. (2010, March). Appendix 15A- *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. DOE Energy Efficiency and Renewable Energy. Retrieved from http://www2.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/sem_finalrule_appendix15a.pdf

US Energy Information Administration. (2010, November). *Country Analysis Briefs: China*. Washington DC. Retrieved from http://www.eia.gov/EMEU/cabs/China/pdf.pdf

US Energy Information Administration. (2010, August). *Country Analysis Briefs: India*. Washington DC. Retrieved from http://www.eia.doe.gov/cabs/India/Full.html

US Energy Information Administration. (2010, July). *Energy Market and Economic Impacts of the American Power Act of 2010*. EIA; SR/OIAF/2010-01.

US EPA. (2011). *Output-Based Environmental Regulations Fact Sheet* – updated September 27, 2011. Retrieved from http://www.epa.gov/chp/state-policy/obr_factsheet.html

US EPA. (2009, October 23). *Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009*. Retrieved from http://www.epa.gov/climatechange/economics/economicanalyses.html

US EPA. (2010, June). *EPA Analysis of the American Power Act of 2010*. Retrieved from http://www.epa.gov/climatechange/economics/economicanalyses.html

US EPA. (2009, April 20). *EPA Preliminary Analysis of the Waxman-Markey Discussion Draft- The American Clean Energy and Security Act of 2009 in the 111th Congress* Waxman-Markey. June 2009. Supplement January 2010. Retrieved from http://www.epa.gov/climatechange/economics/economicanalyses.html

US EPA. (Updated 2011, September 27). *Output-Based Environmental Regulations Fact Sheet*. Retrieved from http://www.epa.gov/chp/state-policy/obr_factsheet.html

United States Geological Survey. (2000). *Mercury in the Environment*. Fact Sheet 146-00. Retrieved from http://www.usgs.gov/themes/factsheet/146-00/

United States Government Accountability Office. (2010). *Coal power plants: Opportunities exist for the DOE to provide better information on the maturity of key technologies to reduce carbon dioxide emissions*. GAO-10-675. Retrieved from http://www.gao.gov/new.items/d10675.pdf

Vermont Law School. (2008). *The Reality of Carbon Taxes in the 21st Century*. A Joint Project of the Environmental Tax Policy Institute and the Vermont Journal of Environmental Law. Retrieved from http://www.vermontlaw.edu/Documents/020309-carbonTaxPaper%280%29.pdf

We have a winner: British Columbia's carbon tax woos skeptics. (2011, July 21).*The Economist*.

Weston, F. (2011, June 17). *Power Sector Policy in Light of Climate Change and the Nuclear Accident in Japan*. Yale-Tsinghua Environment and Sustainable Development Leadership Program. Retrieved from http://www.raponline.org/document/download/id/905

Williams, A., Schultz, R., & Ayres, R. (2009, July). *Reducing Industrial Air Pollution and Greenhouse Gas Emissions Through Technology Standards: Comparing the US, EU and China*. Retrieved from http://www.raponline.org/document/download/id/429

Wilson, R., & Peterson, P. (2011, April 28). *A Brief Survey of State Integrated Resource Planning rules and Requirements*. Prepared for the American Clean Skies Foundation. Synapse Energy Economics.

Wilson, Lucknow, Biewald, Ackerman, & Hausman (2012, October). 2012 Carbon Dioxide Price Forecast (italics). Synapse Energy Economics. Retreived from http://www.synapse-energy.com/Downloads/SynapseReport.2012-10.0.2012-CO2-Forecast.A0035.pdf

World Bank. (2010). *World Development Report 2010: Development and Climate Change*. Washington, DC: World Bank.

World Coal Association. *Improving Efficiencies*. Retrieved from http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies/

World Resources Institute. *Carbon dioxide capture and storage (CCS)*. Retrieved from www.wri.org/project/carbon-dioxide-capture-storage

Worldwatch Institute. (2008, December). Low Carbon Energy: A Roadmap.

Appendix C – Select Policy Summary Tables

Country Carbon Tax Summaries & Resources

Country	Complete Citation	Description of Document	Summary of Policy Implementation
British Columbia	Ministry of Finance, British Columbia. Budget and Fiscal Plan 2008/09 - 2010/11. February 19, 2008. Available at: http://www.bcbudget.gov.bc.ca/2008/bfp/2008_Budget_Fiscal_Plan.pdf	*This document contains the fiscal and economic forecasts for 2008/09 and future years, and includes all material economic, demographic, taxation, accounting policy and other assumptions that underlie the economic, revenue, expenditure, surplus and debt forecasts provided in the document.*	Carbon tax became effective July 1, 2008. The tax applies to all emissions from fossil fuel combustion in BC captured in Environment Canada's National Inventory Report, and includes fossil fuels used for transportation and in all industries, as well as fuel to create heat for households and industrial processes. The initial rate was $10/tonne of GHG emissions, and was set to increase by $5/tonne each year to $30/tonne by 2012. The tax is revenue neutral, with 100% of revenues from the tax being returned to citizens through tax reductions and tax credits.
Quebec	Torys LLP. "Quebec government to implement carbon tax." Torys Climate Change Bulletin. June 12, 2007. Available at: http://www.torys.com/Publications/Documents/Publication%20PDFs/CCB2007-6.pdf National Renewable Energy Laboratory. Carbon Taxes: A Review of Experience and Policy Design Considerations. December 2009. Available at: http://www.nrel.gov/docs/fy10osti/47312.pdf	*Short description of the carbon tax.* *Summary of various country and state carbon taxes.*	Carbon tax of appoximately $3/tonne CO_2 became effective October 1, 2007. Quebec was the first Canadian province to place a tax on energy producers that operate in Quebec and use a large amount of hydrocarbons (producers of gasoline, diesel and heating oil, electricity and natural gas, and coal and propane). The tax rate varies for each fuel - 0.8 cents per litre of gasoline, 0.9 cents for diesel fuel, 0.96 cents for light heating oil, 0.5 cents for propane, and $8.00 per metric ton for coal. Revenues are put into a Green Fund, which helps fund reductions in GHGs and improvements to public transportation.
Alberta	Alberta Environment. Specified Gas Emitters Regulation. Technical Guidance Document for Baseline Emissions Intensity Applications. July 18, 2007. Available at: http://environment.gov.ab.ca/info/library/7811.pdf Customer Bulletin No. 21, Finnish National Board of Customs,	*Provides guidance on whether facilities are subject to regulations and provides instructions on how to fill out application forms.*	The Specified Gas Emitters Regulation applies to facilities that emitted greater than 100,000 tonnes of GHGs in CO_2e in 2003 or any year thereafter. If a facility cannot meet its reduction targets (12% intensity reduction based on the average of the facility's 2003-2005 baseline emissions intensity), it may pay $15/tonne into the Climate Change and Emissions Management Fund to meet reduction requirements.

Country	Complete Citation	Description of Document	Summary of Policy Implementation
Finland	January 2011. Available at: http://www.tulli.fi/en/finnish_customs/publications/excise_tax/excise_taxation/021.pdf Finnish Ministry of the Environment. "Environmentally related energy taxation in Finland." April 14, 2011. Available at: http://www.environment.fi/default.asp?contentid=147208	*Describes energy taxation in Finland.* *Describes updates to the Finnish carbon tax in 2011.*	Finland was the first country to adopt a carbon tax in January 1990, which was based on the carbon content of fossil fuels. The structure of the tax was changed as of January 1, 2011. Liquid fuels and coal are taxed based on both energy content and CO_2 emissions. The CO_2 tax rate for traffice fuels was raised to 50 Euros/ton CO_2 and to 30 Euros for heating fuels. Because of the introduction of the energy component, the weight of CO_2 in the tax for coal, natural gas, and fuel oils was reduced. Fuels used for electricity generation are exempt, but electricity is taxed per kWh. Tax revenues go into the general central government budget.
Sweden	Johansson, Bengt. 2000. "Economic Instruments in Practice 1: Carbon Tax in Sweden." Swedish Environmental Protection Agency. Available at: http://www.oecd.org/dataoecd/25/0/2108273.pdf	*Description of the carbon tax in Sweden*	Sweden adopted a carbon tax on fossil fuels in 1991. When this tax was introduced, the existing general energy taxes were reduced. No tax is levied on fuels used for electricity production. Industry pays only 50% of the carbon tax. One of the most obvious effects of the tax was an increase in the use of biomass in the district heating system. Revenues go to general government accounts.
Norway	International Energy Agency. "Addressing Climate Change, Policies and Measures, CO_2 Tax, Norway." Available at: http://www.iea.org/textbase/pm/?mode=cc&id=3548&action=detail. Accessed September 6, 2011.	*IEA database that provides a description of the carbon tax in Norway*	Two CO_2 taxes were adopted in Norway in 1991. The first applies to mineral oil (excluding fisheries), petrol, auto diesel, natural gas, and LPG. It applied to coke and coal until January 2003. The second applies to emissions from offshore oil and gas production, and is paid per litre of oil and natural gas liquids and per standard cubic meter of gas burnt or emitted directly to air on platforms, installations or facilities. The CO_2 tax currently applies to about 68% of all CO_2 emissiosn and about 52% of GHG emissions.
Denmark	Vermont Law School. The Reality of Carbon Taxes in the 21st Century. A Joint Project of the Environmental Tax Policy Institute and the Vermont Journal of Environmental Law. 2008. Available at: http://www.vermontlaw.edu/Documents/020309-carbonTaxPaper%280%29.pdf	*Book published by Vermont Law School*	Denmark's CO_2 tax took effect in May 1992. Fossil fuels are subject to both a CO_2 tax and an energy tax, but when the CO_2 tax was implemented, the energy tax was lowered, keeping the overall tax rate the same. Fossil fuels used to generate electricity are exempt from the CO_2 tax, but there is a separate CO_2 tax on electricity consumption. Industry pays different tax rates based on usage.

Country	Complete Citation	Description of Document	Summary of Policy Implementation
Netherlands	Netherlands Ministry of Housing, Spatial Planning and Environment. The Netherlands' Tax on Energy: Questions and Answers. 2004. Available at: http://www.wind-works.org/FeedLaws/Netherlands/NLEnergytax2004.pdf	*Describes the regulatory energy tax and the ways in which the revenues are recycled back into the economy.*	A carbon tax affecting large energy users was first adopted in the Netherlands in 1990, but in 1992 was replaced with a 50/50 carbon/energy tax. A tax targeting small-scale energy consumers was introduced in 1996. In 2004 these taxes were combined into one single tax, and it applies to antural gas, electricity, blast furnaces, coke ovens, refinery and coal gas, coal gasification gas, gasoline, diesel, and light fuel. A tax on coal remains separate. Revenues are used to fund reductions in personal and corporate income taxes. The tax rate for households is much higher than the tax rate paid by large energy users.
United Kingdom	Vermont Law School. The Reality of Carbon Taxes in the 21st Century. A Joint Project of the Environmental Tax Policy Institute and the Vermont Journal of Environmental Law. 2008. Available at: http://www.vermontlaw.edu/Documents/020309-carbonTaxPaper%280%29.pdf	*Book published by Vermont Law School.*	The Climate Change Levy (CCL) was introduced in the UK in April 2001. The consumption of natural gas, electricity, coal, and liquefied petroleum gas are subject to the CCL, which applies only to commercial and industrial use and exempts household use.
Switzerland	International Energy Agency. "Global Renewable Energy, Policies and Measures, Implementation of the Law on the Reduction of CO2 Emissions." Available at: http://www.iea.org/textbase/pm/?mode=red&action=detail&id=514	*IEA database that gives a brief description of the carbon law in Switzerland*	The carbon tax in Switzerland was implemented in 2008, due to the fact that voluntary measures were not sufficient to meet GHG reduction targets. The tax applies to all imported fossil fuels, unless they are used for energy production. Gasoline and diesel fuels are not subject to the tax. Companies may be exempt from the tax if they choose to reduce CO_2 emissions through voluntary measures. Revenue from the tax is to be refunded to the public and industry. The maximum tax is set at 210 CHF/tonne CO_2.
Costa Rica	Congressional Research Service. "Costa Rica: Background and US Relations." February 22, 2010. Available at: http://assets.opencrs.com/rpts/R40593_20100222.pdf	*Document describes Costa Rica and has a sentence on the carbon tax.*	The tax on carbon emissions was implemented in 1997. Tax is 3.5% of the market value of fossil fuels, with revenues going into a national forest fund to pay indigenous communities to protect their forests.
Australia	"Australia's Carbon Tax: Breaching the Brick Wall." *The Economist*. July 11, 2011. Available at: http://www.economist.com/blogs/banyan/2011/07/australias-carbon-tax	*Blog post about the announcement of the CO_2 tax.*	Carbon tax legislation was introduced to Parliament on September 13, 2011. Australia's 500 most polluting companies would pay A$23/tonne of CO_2 emissions. Half of the tax revenue will compensate households for higher electricity and living costs, while another 40% of revenue will help business and industry to switch to cleaner forms of energy. The bill faces a final vote on October 12. Three years after the tax is implemented, it will be replaced by an emissions trading scheme.

Country	Complete Citation	Description of Document	Summary of Policy Implementation
Australia *(continued)*	Thompson, Jerry. "PM Introduces Carbon Price Legislation." ABC News. September 14, 2011. Available at: http://www.abc.net.au/news/2011-09-13/pm-introduces-carbon-tax-legislation/2897250	*ABC News article about introduction of CO_2 tax bill to Australian Parliament.*	
India	Ministry of Environment and Forests, Government of India. "India: Taking on Climate Change. Post-Copenhagen Domestic Actions." June 30, 2010. Availabe at: http://www.indiaenvironmentportal.org.in/files/India%20Taking%20on%20Climate%20Change.pdf	*Describes all of India's actions on climate change.*	In 2010 India announced a levy on coal at the rate of 50 rupees ($1 USD) per ton. The tax applies to domestically produced and imported coal, with tax revenues going to the National Clean Energy Fund. The Fund will support research, new projects in clean energy technologies, and environmental remediation programs.
France	France May Earn 200 Million Euros From Planned Carbon Tax, September 28 2011	*Article on the proposed carbon tax in France.*	A proposed carbon tax would be levied on 2011 pretax revenue at French companies participating in the EU ETS and emitting more than 60,000 metric tons of CO_2 per year. The tax rate will be between 0.08 and 0.12 percent. Proceeds from the tax would fund the purchase of CO_2 allowances for new power plants. The tax still must be approved by French parliament.
China	Reuters. "China rollouts nationwide resource tax from Nov 1." October 10, 2011.	*Article on the resource tax in China*	China is putting a nationwide tax on domestic sales of crude oil, natural gas, coking coal and rare earths beginning November 1, 2011. Sales of crude oil and naturals gas would be taxed at a rate of between 5 and 10%. Rare earth ores would have a sales tax of 0.40-60 yuan per ton, and coking coal would have a tax of 8-20 yuan per ton. Taxes on other types of coal are set at 0.03-5 yuan per ton.

Country Carbon Reduction Strategies

Country	Description	Current Status and Efforts	Gaps in Knowledge and Efforts	Sources
China	*In December 2009, China announced its carbon intensity reduction target at the Conference of the Parties in Copenhagen. China aims to reduce domestic carbon intensity by 40 to 45 percent of 2005 levels by 2020. The carbon intensity target covers CO_2 emissions from fossil-fuel consumption and industrial activity, but will not cover emissions from land use and forestry.*	China's efforts between 2006 and 2010 have successfully slowed the growth of its CO_2 emissions. China will only be able to achieve its target through practive policymaking and substaintial new investments similar to those undertaken over the last five years; however, the country will fall short of its target without undertaking new efforts. In China's Twelfth Five Year Plan, key targets include a 16% energy intensity reduction target, a 17% carbon intensity reduction target, and a target to increase non-fossil fuel energy sources to 11.4% of primary energy consumption from the current 8.3%. Also included in the Plan is a cap on total energy use of 4 billion tons of coal equivalent annually. These targets are in line with China's carbon intensity reduction goal of 40-45% by 2020.	Without extended efforts to continue to reduce energy intensity past 2010, China's energy consumption grows. Completion of previous commitments will only result in reductions of 37% from 2005 levels by 2020. New policies to reduce energy intensity are necessary to meet the stated targets.	"Cohen-Tanugi, David. *Putting it into Perspective: China's Carbon Intensity Target*. NRDC White Paper. October 2010. Available at: http://china.nrdc.org/files/china_nrdc_org/Chinas%20Carbon%20Intensity%20Target%20in%20Perspective.pdf Switchboard: Natural Resources Defense Council Staff Blog. *China Puts Forth Energy Intensity, Carbon Intensity and Total Energy Consumption Targets in Twelfth Five Year Plan in Effort to Tackle "Unsustainable Economic Growth."* March 5, 2011. Available at: http://switchboard.nrdc.org/blogs/bfinamore/china_puts_forth_energy_intens.html
India	*On December 3, 2009 India announded that it will cut its carbon intensity by 20-25% from 2005 levels by 2020. The target does not include emissions from agriculture.*	The emissions intensity reduction target is based on analysis of the impact of various measures the government has announced to lower emissions: a planned amendment to the Energy Conservation Code, new fuel efficiency standards that take effect in 2011, deploying super-critical and cleaner technologies in coal-fired power plants, increased forest cover to sequester 10 percent of its annual emissions, increasing the fraction of eletricity from wind, solar and small hydro from the current 8% to 20% by 2020, and adoption of new green building codes by 2012. All of these actions have been detailed under either the National Action Plan on Climate Change or under existing regulatory policies. In May 2010, India became the first developing country to publish its 2007 emissions inventory and promised to release it every other year.	"The voluntary and non-binding commitment is unlikely to provide an significant deviation from the 'business as usual' path that india is likely to take in its progression to development. Domestically, there is expected to be much more debate on what carbon intensity cuts will imply, particularly for the manufacturing sector in India. Questions will also be raised as to whether India should adopt a softer 'energy intensity' metric, rather than a 'carbon intensity' one."	Policy Brief. India announces energy intensity target. India Climate Portal. December 2009. Available at: http://www.indiaclimateportal.org/component/option,com_policybrief/view,policybriefdetail/id,20

Country	Description	Current Status and Efforts	Gaps in Knowledge and Efforts	Sources
Brazil	*Brazil announced a target to reduce emissions growth by 36-39% below business-as-usual levels by 2020 - a level estimated to bring down Brazil's emissions to 1994 levels.*	Over half of the proposed reductions are expected to come from efforts already underway to lower deforestation in the Amazon, which accounts for about 2/3 of Brazil's total emissions. The deforestation rate has dropped recently, though it is unclear how much of the drop is a result of policy changes - the recent crack-down on illegal logging and enhanced enforcement of land licensing - versus the economic crisis and the resulting reduction in the global demand for beef and soy production, the typical drivers for deforestation. Brazil must take significant steps to implement its intensity reduction targets, which means improving the management of the Amazon, implementing land tenure laws, addressing excessive fire outbreaks, reducing subsidies to competing land uses that drive deforestation, tackling emissions from agriculture and ranching, and reversing the trend of incresing carbon intensity in the energy sector.	Because the target is a drop from BAU, and not from current emissions levels, the emissions intensity reduction target translates to a 15-18% reduction from 2005 levels. The government has not released the methodology for the calculation of BAU emissions, and there is debate as to the economic growth rate that should have been assumed in the calcuations. A higher growth rate would result in higher emissions estimates, and an inflated BAU would make the reductin target easier to achieve.	Fransen, Taryn. Brazil Pledges Ambitious Emissions Reductions. World Resources Institute. November 18, 2009. Available at: http://www.wri.org/stories/2009/11/brazil-pledges-ambitious-emissions-reductions
Indonesia	*Indonesia pledged to reduce greenhouse gas emissions by 26% by 2020 compared to business as usual emissions from forestry, energy and waste.*	Emission cuts from forests would be achieved by combating illegal logging, avoiding deforestation, rehabilitating land and forest in watershed areas, improving fire management, and restoring forest ecosystems, including the tree planting program of "one man-one tree." The goverment needsto improve peat land management and build capacity in managing peat fires, launch energy conservation programs for the private sector and households, improve public transport including trains and mass rapid transit, and envorce a 2008 law on solid waste requiring all districts to change from open dumping to more sanitary landfill systems and to separate methane and use it as a sorce of electricity.	Indonesia needs to collect funds from other nations in order to meet emissions reductions targets.	Simamore, Adianto P. and Stevie Emilia. Indonesia needs Rp 83 trillion to meet emission cut target. *The Jakarta Post.* December 19, 2009. Available at: http://www.thejakartapost.com/news/2009/12/19/indonesia-needs-rp-83-trillion-meet-emission-cut-target.html
Israel	*Israel plans to reduce emissions by 20% by 2020 compared to the business as usual case.*			
Mexico	*Mexico plans to reduce emissions by 30% by 2020 compared to the business as usual case.*			

Country	Description	Current Status and Efforts	Gaps in Knowledge and Efforts	Sources
Singapore	*Singapore plans to reduce emissions by 16% by 2020 compared to the business as usual case.*		Singapore would only commit to these reductions if there was a legally binding global deal that obliges all countries to cut emissions, and if other countries offer significant pledges.	
South Africa	*South Africa plans to reduce emissions by 34% by 2020 compared to the business as usual case.*		The South African government states that developing countries like South Africa would need financial help from developed economies to meet emissions reduction goals, with some of the aid being used to acquire the technology needed to reach targets.	South Africa to cut carbon emissions by 34%. BBC News. December 7, 2009. Available at: http://news.bbc.co.uk/2/hi/africa/8398775.stm
South Korea	*South Korea plans to reduce emissions by 30% by 2020 compared to the business as usual case.*	South Korea plans to achieve reduction targets through the increased use of hybrid cars, renewable and nuclear energy, LEDs for energy efficiency, and smart grid policies. The South Korean government also states that it would invest in environment-related industries.		South Korea, Mexico to Set CO_2 Reduction Goals. Environmental Leader. August 6, 2009. Available at: http://www.environmentalleader.com/2009/08/06/south-korea-mexico-to-set-co2-reduction-goals/

The Regulatory Assistance Project (RAP) is a global, non-profit team of experts focused on the long-term economic and environmental sustainability of the power and natural gas sectors. We provide technical and policy assistance on regulatory and market policies that promote economic efficiency, environmental protection, system reliability, and the fair allocation of system benefits among consumers. We work extensively in the US, China, the European Union, and India.
Visit our website at **www.raponline.org** to learn more about our work.

The Regulatory Assistance Project

Beijing, China • Berlin, Germany • Brussels, Belgium • Montpelier, Vermont USA • New Delhi, India

www.raponline.org